Social-ecological factors and preventive actions decrease the risk of dengue infection at the household-level: results from a prospective dengue surveillance study in Machala, Ecuador

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ABSTRACT

Background

In Ecuador, dengue fever and other febrile diseases transmitted by the *Aedes aegypti* mosquito are among the greatest public health concerns in urban coastal communities. Community- and household-level vector control is the principal means of controlling disease outbreaks. The aim of this study was to assess the impact of dengue prevention knowledge, attitudes, and practices (KAPs), as well as social-ecological factors, on the presence or absence of acute or recent dengue infections in the household.

Methods

As part of dengue surveillance in Machala, Ecuador, we invited individuals with an acute dengue illness to participate, along with other members of the household and members of four neighboring households. We conducted diagnostic testing for dengue on all study participants, and we surveyed heads of households (HOHs) regarding KAPs. We compared KAPs and social-ecological factors between households with (n=139) versus without (n=80) acute or recent dengue infections, using bivariate analyses and multivariate logistic regression models with and without interactions.

Results

In bivariate analyses (but not multivariate modeling), the presence of dengue infections was positively associated with HOHs who were male, employed, and of younger age than households without recent or acute dengue infections ($p<0.05$). Dengue infection was not associated with knowledge or attitude, or on reported barriers to prevention activities. Significant risk factors in multivariate models included proximity to abandoned properties, interruptions in piped water, and shaded patios ($p<0.05$). Significant protective factors included use of mosquito nets, fumigation inside the home, piped water inside the home ($p<0.05$).

Discussion

Specific effective actions that can be considered to decrease the risk of dengue infections in the household include alteration of shade on the property, fumigating inside the home, and use of mosquito nets. Community-level interventions include clean-up of abandoned properties, daily trash pick-up, and reliable piped water inside houses. These interventions could potentially reduce the risk of other diseases transmitted by the *Ae. aegypti* mosquito, such as chikungunya and Zika fever.

Author summary

Dengue, chikungunya and Zika viruses are transmitted to people primarily by the *Aedes aegypti* mosquitoes in tropical and subtropical regions. Diseases transmitted by the *Ae. aegypti* mosquito are a growing public health concern. Mosquito control is the principal means to preventing and controlling disease outbreaks, since vaccines are not readily available. In this study, we compared the characteristics of households with and without dengue infections in the city of Machala, Ecuador. We found that risk factors for dengue infection included proximity to abandoned properties, interruptions in the piped water supply, and a highly shaded patio. Protective factors included the use of mosquito nets, fumigation inside the home, and piped water inside the home. These findings can be used to inform targeted vector control interventions by the public health sector at the household and community levels.

Keywords: dengue infection, Aedes aegypti, vector-borne, prevention, KAP, Ecuador

INTRODUCTION:

Dengue fever is a febrile illness caused by the *Flavivirus* DENV, of which there are four serotypes (DENV1-4). Infections may be asymptomatic, or have symptoms ranging from fever, rash, and joint pain to hemorrhage, shock and sometimes death. About 3.9 billion people, in 128 countries, live in areas that are at risk of infection with dengue viruses (1,2). The dengue virus is transmitted primarily by the *Aedes aegypti*, a tropical mosquito that has adapted to live and breed in urban environments (3,4). *Ae. aegypti* also transmits chikungunya and Zika viruses, which are now co-circulating with DENV in populations in the tropics and subtropics (5,6). Because vaccines and therapeutics against these diseases are not available, with the exception of the dengue vaccine in several countries, community-level and household-level vector control is the principal means of controlling disease outbreaks (7).

The female mosquitoes will oviposit in most any water-bearing container, which become the habitat of juvenile mosquitoes, such as water storage drums, tires, discarded containers, and flower pots (8-11). Therefore, preventive practices against dengue include covering water storage containers, eliminating standing water, adding larvicides to water containers, and general clean-up of potential water receptacles (12,13). Placing screens on windows to protect against the mosquito vector is also effective in preventing dengue (13). Indoor residential spraying in households has been shown to decrease the dengue vector *Ae. aegypti* in the household (14), and may decrease the risk of further infections in households with dengue infections (15). Other vector control methods include Wolbachia infections and introduction of genetically-modified sterile mosquitoes into the population (16).

One aspect of community interventions against dengue is an effort to change people's knowledge, attitudes and practices (KAPs), under the model that increasing knowledge and changing attitudes toward dengue will help lead to an increase in preventive practices, and ultimately result in the decreased spread of dengue infections. To date, many studies have been published on the KAPs of people in dengue-endemic areas, with varied results. While most demonstrate that knowledge and attitude are associated with preventive practices (17-28), it should be noted that due to resource needs and other barriers, knowledge alone is not enough to create a sustainable change in behavior (29).

Studies of the association between social-demographic factors and KAPs have produced conflicting results. Demographic variables that have been reported to be associated with KAPs in one or more study include sex, age, marital status, education, literacy, employment, occupation, income, ethnicity, and religion (17,21,22,24,26,28,30-35). Other social-ecological factors associated with KAPs include frequent fogging of the neighborhood (20), adequate resources and assistance from public health staff (21), presence of dengue in the neighborhood (36,37), presence of mosquitoes in the neighborhood (35), internet access (30), community support or governmental infrastructure to control neighboring and public spaces (38), and having a reputable source of information such as health personnel or head of the village (27).

Less is known about the impact of social-ecological factors and KAPs on the prevalence of dengue infection as the ultimate outcome of interest. A recent case-control study in China showed that housing conditions, dengue knowledge, individual prevention actions, and elimination of larval habitat was associated with the dengue risk (39). In other studies, the presence of dengue antibodies (IgG, indicative of a past infection) in individuals was associated with dengue knowledge, housing density and housing conditions (37, 40-44).

Other studies have identified the attributes of communities considered to be dengue transmission hotspots, including demographics, dengue knowledge and prevention actions.

In Ecuador, dengue fever and other febrile diseases transmitted by the *Ae. aegypti* mosquito, are among the greatest public health concerns in urban coastal communities, which have the highest burden of disease in the country. Over a five-year period (2010 to 2014), 72,060 cases of dengue illness were reported in Ecuador, with an annual average of 14,412 cases (45). The prevalence of dengue illness peaks in the rainy season from February to May. Based on active surveillance in 2014 and 2015 (46), the prevalence is greatest in children and young adults under the age of 20, who accounted for 51% of all acute or recent dengue infections. Secondary infections present with more symptoms, and are more likely to result in hospitalization. The proportions of primary and secondary dengue infections vary from year to year, as do the dominant DENV serotypes in circulation. For every medically-attended case, there are about three additional unreported dengue infections, 43% of which do not have any dengue symptoms.

The Ministry of Health is the primary government institution responsible for dengue control in Ecuador. Control includes a schedule of indoor residual spraying with deltamethrin and ultra-low volume with malathion fogging in high-risk urban communities at the beginning of the rainy season, and household visits by inspectors to treat water-bearing containers with an organophosphate larvicide (abate/temefos). Additionally, the MOH conducts focal vector control (including indoor residual spraying) in and around the households and neighboring households of people with suspected or laboratory-confirmed dengue infections. Response times for such activities are variable, depending on the resources available to the MOH. Educational interventions for dengue prevention include television and radio campaigns, fliers, outreach to patients in Ministry of Health clinics, and community education meetings. KAP studies provide important baseline information to guide the development of targeted interventions that provoke desired behavioral changes by community members (e.g., water storage and health care seeking behaviors).

Prior studies in Ecuador by our group identified social-ecological risk factors for the presence of *Ae. aeygpti* using entomological household surveys, and for dengue infections using geo-referenced epidemiological case reports, aggregated to the neighborhood level (47,48). These studies found that dengue risk was associated with older age and female gender of the head of the household, greater access to piped water in the home, poor housing condition, household water storage practices, higher housing density, and lack of knowledge and low risk perception. Prior studies also assessed the dengue KAP of community members and health care providers (49,50). Community members reported that dengue control required considerable time and resources, which was a greater challenge for low-income households (51), and healthcare providers reported insufficient resources to diagnose and treat dengue. Community members and health care providers had common misconceptions about dengue epidemiology and the behavior of the mosquito vector (i.e., biting habits, larval habitat), thus limiting their ability to prevent the disease in their homes.

As part of an ongoing dengue surveillance study in Machala, Ecuador (46), we invited individuals with an acute dengue illness (index cases) to participate in the study, along with other members of the household and members of four neighboring households located within 200 m of the index house. We conducted diagnostic testing for dengue on all study participants, and we surveyed heads of households regarding household demographics, housing condition, and dengue prevention KAPs. Here, we present the results of analysis of the association between these risk factors and the presence or absence of acute or recent dengue infections in the household in 2014 and 2015.

METHODS:

Ethics Statement:

This protocol was reviewed and approved by Institutional Review Boards (IRBs) at SUNY Upstate Medical University, the Luis Vernaza Hospital in Guayaquil, Ecuador, and the Ecuadorean Ministry of Health. Prior to the start of the study, all participants engaged in a written informed consent or assent process, as applicable. In the event the participant was unable to participate in the informed consent or assent process, a recognized health-care proxy represented them in the process and documented consent. The study population included children (>6 months) to adults.

Study Site:

Machala, Ecuador (population of approx. 276,000) is the capital city of El Oro Province and is a major port in the coastal lowland region (Figure 1). It is located 70 kilometers north of the Peruvian border. Machala is typical of mid-sized cities in Latin America that experienced rapid, unplanned growth from 1960 to 1980, resulting in uneven access to piped water, garbage collection, and paved roads in the urban periphery (48,50).

In Ecuador, dengue causes the greatest burden of mosquito-borne febrile illness and is a major public health concern. Historically, DENV was eradicated from Ecuador in the 1950s with support from the Rockefeller Foundation and the Pan American Sanitary Bureau, primarily through the use of DDT to control *Ae. Aegypti* (52,53). Following a weakening of the vector control program and the re-introduction of *Ae. aegypti* in the 1970s and 1980s, DENV-1 re-emerged in Ecuador in 1988 causing an major epidemic of classic dengue fever (54). From 1993 to 1999, three serotypes circulated: DENV-1, DENV-2 (American strain), and DENV-4. In 2000, DENV-3 and DENV-2 (Asian strain) were introduced and the first cases of severe hemorrhagic dengue were subsequently reported (53,55). Dengue is now hyper-endemic in the coastal lowland region, where all four serotypes have co-circulated since the year 2000 (55,56). In 2014 and 2015, the years of this study, there were an estimated 186 to 201 cases of dengue infection per 10,000 people per year (46).

Study design:

The ascertainment and recruitment of households into this study is described in detail elsewhere (46). Briefly, individuals who present with clinically-suspected dengue at one of five clinical sites operated by the Ministry of Health in Machala, Ecuador are invited to participate in this ongoing study. In this paper, we present an analysis that includes participants from January 2014 through September 2015.

After giving informed consent, the participants were tested for dengue infection using the dengue NS1 rapid strip test (PanBio). A random subset of dengue rapid test-positive individuals was invited to participate in a household study, and these households are referred to herein as index households. In addition, individuals from four neighboring households (within 200m) were invited to participate in the household study, and are referred to as associate households (57).

The household study consisted of three parts: a survey of the head of the household, interviewer observation of household characteristics, and blood draw of each household member who was available and who consented for dengue testing. The survey was completed by the head of the household (self-identified), or a proxy (adult age 18 years or greater who was at home during the study team visit, usually the husband or wife) if not available. The survey included questions about the demographics of the head of the household, household demographics, access to water and sewage services, water storage and use practices, knowledge and attitudes about dengue, and prevention activities employed by members of the household. The interviewers' observations included condition of the house and patio, construction materials, presence and condition of screens in windows and doors, and presence of uncovered standing water on the property. The survey instrument has been provided in English (Supplementary Text 1) and Spanish (Supplementary Text 2)

Blood samples from study participants were tested for dengue using RT-PCR, NS1 rapid strip test, and PanBio commericial ELISA assays for NS1 and dengue IgM assays. See Stewart Ibarra, 2017, for details of the diagnostic testing procedures (46). A participant was categorized as having an acute or recent dengue infection if he or she tested positive for any one of these tests. Households were characterized as having dengue present if anyone in the household tested positive for dengue. All index households, by definition, had dengue present.

Statistical analysis:

Statistical analyses were conducted using SAS version 9.4. Bivariate analyses of households with versus without dengue were conducted using Chi-square, Fisher's Exact, or t-tests. Multivariate logistic regression was conducted in two steps using the proc logistic command with backward selection. In the first step, all potential main effects were included in the analysis. In the second step, two-way interactions between all of the variables identified in the first step were added to the analysis.

RESULTS:

As part of a larger dengue surveillance and research study, we conducted a household study that consisted of a head of household survey, interviewer observation, and testing for acute or recent dengue infections. From January 2014 through September 2015, a total of 219 households were included in the household study: 44 index households and 175 associate households (Figure 1). These households were distributed across the city of Machala, thereby distributing a range of social-ecological conditions. Most of the households (n=161) were recruited during 2014 and the rest (n=58) were from 2015. The head of the household was female in 24.2% of households, and had a mean age of 47.8 (SD=13.6) years. The households were classified as having (n=139) or not having (n=80) a member with an acute or recent dengue infection.

We compared the social-ecological characteristics and reported barriers to dengue prevention in households with versus without dengue infections (Table 1). In bivariate analyses, the presence of dengue infections was positively associated with heads of households who were male, employed, and of younger age than households without dengue ($p<0.05$). Households with dengue infections were more likely to have a patio with more than 50% shade or to have adjacent abandoned property, and were less likely to have piped water inside of the house or have their trash picked up daily ($p<0.05$).

We also compared KAPs in households with versus without dengue infections (Table 2). The households with versus without dengue infections did not differ on any of the five knowledge and attitude questions, or on reported barriers to dengue prevention activities. We asked survey respondents about whether they engaged in twelve different preventive activities. The most commonly-reported dengue prevention activities were eliminating standing water

(37.9%), covering water containers (37.9%), fumigating inside the house (37.9%), cleaning the garbage (37.0%), applying chemicals to standing water (i.e., larvicides) (25.6%) and using mosquito nets (20.6%). Households with dengue infections were more likely to report that they applied chemicals to standing water, and were less likely to report the use of indoor fumigation (Table 2). The other prevention activities did not differ between households with versus without dengue infections.

All social-ecological factors and KAPs were used in a logistic regression analysis to identify a multivariate model to predict the presence of an acute or recent dengue infection in the household (Table 3). Model 1 included main effects only, and demonstrated that abandoned properties nearby, frequent interruptions in water supply, and patios with >50% shade were risk factors for dengue. Protective factors in this model included piped water inside the house, fumigation inside the house, use of mosquito nets, and reporting cost of as a barrier to protective practices. The strongest factor in this model was the presence of >50% shade on the patio, with an adjusted odds ratio (adj. OR) of 16.2 (95%CI: 2.98-88.1, p=0.001).

We then added all two-way interactions of these variables to the model, and eliminated non-significant factors and in a backward selection process. In Model 2, the presence of a patio with more than 50% shade was highly predictive of dengue infections in the household, with an adj. OR of 13.3 (95%CI: 3.2-54.3, p=0.0003), compared to households without a patio or with a patio that had <50% in the shade. Use of mosquito nets was protective against dengue infections in this model (adj. OR=0.39. 95%CI: 0.18-0.85, p=0.02). There were two significant interaction terms in Model 2. First, fumigation in the house was protective against dengue when there were no abandoned houses nearby (adj. OR=0.19, 95%CI: 0.09-0.42, p<0.0001) but not when there was one or more abandoned properties nearby. Second, fumigation was protective when there was piped water inside the house (adj. OR=0.19, 95%CI: 0.09-0.39, p<0.0001) but not when there was no piped water in the house.

DISCUSSION:

In this study, we found that specific social-ecological factors and preventive actions were associated with effective dengue control. The strongest predictor of dengue infections in the household, in both multivariate models, was having a patio that was more than 50% shaded with an adj. OR of 12 to 16. Patio shade and patio condition have been shown to be associated with the presence of *Ae. aegypti* mosquitoes in prior studies, including studies in Machala (48, 58). Our results also support the use of mosquito nets, as people who did not report the use of mosquito nets were about twice as likely to live in a household that had an acute or recent dengue infection. Other studies have shown associations among dengue infections, KAPs and demographic factors. In our study, with dengue infection as the outcome, demographic variables are not significant factors in the multivariate model. Likewise, knowledge and attitude responses were not associated with dengue in the household.

Abandoned properties nearby and lack of piped water inside the house were significant predictors of dengue infections in the house when only main effects were included in Model 1, but not in Model 2. Likewise, fumigation inside the home was found to be protective against dengue infections in Model 1, but only in conjunction with other factors in Model 2. The statistical interactions suggest that the risk factors of abandoned properties and lack of piped water inside the house cannot be overcome with fumigation inside the home. That is, fumigation inside the home is only effective in the absence of abandoned properties nearby and the presence of piped water inside the house. Prior studies in Peru (14) and Australia (15) demonstrated the impacts of indoor residual spraying on a reduction on *Ae. aegypti* densities and dengue risk. In our study, 37.9% of participants reported fumigation inside the house as a preventive action, but we did not distinguish between fumigation by the Ministry of Health versus by the household members themselves. Many people in Ecuador fumigate their own homes, and there are a variety of products available on the market (51). It should be noted that insecticide resistance in *Ae. aegypti* has been reported in this region (A. Stewart, pers. comm.). Resistance is a major public health concern, since insecticides are one of the primary means of controlling *Ae. aegypti* transmitted diseases (59). Studies are ongoing to document the prevalence of resistance to specific groups of insecticides, to inform vector control interventions.

In this study, 20.6% of households reported the use of mosquito nets, and use of nets was associated with a 2.6-fold decreased risk of dengue in the household. Other studies have failed to find an association between mosquito net use and dengue infections (60), presumably because *Ae. aegypti* feeds during the day (morning and afternoon) (61). However, nets could provide protection for children napping during the day, and could prevent further spread of the virus by viremic individuals resting at home under mosquito nets during the day (62). We did not distinguish between insecticide-treated and untreated mosquito nets, nor did we gather information on the use of nets (i.e., bed nets versus curtains). Insecticide-treated bed nets offer protection both as a physical barrier during daytime sleeping, and by killing mosquitoes that come into contact with them. Further research is needed to elucidate the association between mosquito nets and dengue protection observed in this study.

There were two additional social-ecological factors that were significant in bivariate analyses but not multivariate model: daily trash pick-up, and application of chemicals to standing water. Applying chemicals to standing water positively correlated with having dengue in the household, probably because those who responded “yes” had standing water to begin with. In our experience, chemical application refers to the larvicides (temefos/abate) provided by the Ministry of Health, the use of bleach by households to to purify the water. Daily trash pick-up appears to be protective against dengue in the household, and could be considered by communities as part of dengue prevention programs, even though it was not included in the multivariate model.

The results of this study contribute to a growing body of knowledge on the role of social-ecological factors and KAPs on the prevalence of dengue infection. Risk factors vary by location and over time, highlighting the importance of local studies to understand disease risk factors and to inform localized interventions. In a recent case-control study in China, Chen and colleagues showed that living in old apartment buildings increased the risk of dengue infection, while knowledge of dengue fever, use of repellent, and cleaning trash/water containers decreased the risk of dengue (39). In studies from Camaroon, India, the Texas-Mexico border, Sudan, and Key West, Florida, USA, the presence of dengue antibodies (IgG, indicative of a past infection) in individuals was associated with lack of knowledge about dengue fever, high household density (more than three people per bedroom), more than two children in the home, water storage, lack of air conditioning, and poor housing conditions (40-44). In a Malaysian study, the seroprevalence of dengue IgG in school children was positively associated with apartment/condominium homes and households in a rural setting, while neighborhood fogging, preventive actions and knowledge were associated with the absence of seropositivity in the community’s school children (37). In a community-level study in Singapore, investigators compared the attributes of communities that were and were not transmission dengue hotspots. They found that protection factors included male heads of households, higher education, having landed property, knowledge of preventive practices, and practicing certain preventive activities (changing water in vases or bowls on alternate days, and removing water from flower pot plates on alternate days) (36).

The main strength of this study is that we were able to look at acute and recent dengue infections as the outcome variable of interest, while many prior studies look at the use of preventive activities. The main limitation to this study is that we have no way of knowing where the individuals with dengue were infected. In addition to the home, individuals could also have been exposed at other locations such as school or work, and we do not account for risk factors at these locations. In the bivariate analyses, employment by the head of the household was a risk factor for dengue, suggesting that exposure at work may be an important factor. A second limitation is that most of the dengue-positive households in this study were index cases, all of whom were identified through health care facilities. Bias related to health care-seeking behavior may have been introduced as a result. Ideally, the analysis would include only associate households, but the sample size would have been too small for statistical analysis. We chose to include all households in the analysis in order to maximize the power of our analysis. A third limitation is that it is not possible to rule out the possibility that members of households with acute or recent dengue infections have recently changed their behavior in response to the dengue infection. Finally, for individuals who tested positive only for IgM, the infection could have occurred up to two to three weeks prior.

Our results suggest that specific actions at the household and community levels could reduce the spread of dengue infections. In resource-limited communities such as Machala, public health actions by the Ministry of Health could focus vector control interventions in high-risk households and communities. Tun-Lin and colleagues have shown that targeted interventions based on either types of water containers (63) or conditions of the household (64) can be at least as effective as non-targeted interventions. As in those studies, we found that homes next to abandoned properties and homes with heavily-shaded patios should be high-priority homes for interventions. However, we did not find any specific container type to be associated with dengue in the household. Future studies should investigate the impact of the following interventions on dengue infections: alteration of shade on the property, fumigating inside the home, and use of mosquito nets. Community-level interventions include clean-up of abandoned properties, daily trash pick-up, and reliable piped water inside houses. Our results suggest that these community actions moderate the effectiveness of fumigation in prevention of dengue infection, and thus represent very important components of a community approach to dengue prevention. These community and household level interventions should also provide some protection against other *Ae. aegypti*-borne diseases such as chikungunya and Zika fever.

Availability of data and materials

Since the publication includes confidential patient information, we cannot make the datasets fully available with the paper. This would be in violation of confidentiality as expressed in the Informed Consent approved by U.S. and Ecuadorian IRBs. This study reports the results of a two-year arbovirus surveillance study, where we collected sensitive patient information including demographics, clinical presentation, home address, and final disease diagnosis. The de-identified datasets in the current study are available from Lisa Ware at warel@upstate.edu on reasonable request.

Competing Interests

The authors declare no competing interests, financial or non-financial.

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Authors' Contributions

AMSI and TE had overall responsibility for the study, which included the study conception, collaboration with co-authors on the study protocol, and oversight of data collection. AK analyzed the data and drafted the manuscript. All co-authors provided critical revision of the article and approved the final manuscript.

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References:

(1) Brady OJ, Gething PW, Bhatt S, Messina JP, Brownstein JS, Hoen AG, et al. Refining the global spatial limits of dengue virus transmission by evidence-based consensus. PLoS Negl Trop Dis 2012;6(8):e1760.

(2) Jentes ES, Lash RR, Johansson MA, Sharp TM, Henry R, Brady OJ, et al. Evidence-based risk assessment and communication: a new global dengue-risk map for travellers and clinicians. J Travel Med 2016 Sep 13;23(6):10.1093/jtm/taw062. Print 2016 Jun.

(3) Espinosa MO, Polop F, Rotela CH, Abril M, Scavuzzo CM. Spatial pattern evolution of *Aedes aegypti* breeding sites in an Argentinean city without a dengue vector control programme. Geospat Health 2016 Nov 21;11(3):471.

(4) Espinosa M, Weinberg D, Rotela CH, Polop F, Abril M, Scavuzzo CM. Temporal Dynamics and Spatial Patterns of *Aedes aegypti* Breeding Sites, in the Context of a Dengue Control Program in Tartagal (Salta Province, Argentina). PLoS Negl Trop Dis 2016 May 25;10(5):e0004621.

(5) PAHO. Zika cases and congenital syndrome associated with Zika virus reported by countries and territories in the Americas, 2015 - 2016. Cumulative cases. 2017; Available at: http://www.paho.org/hq/index.php?option=com_docman&task=doc_view&Itemid=270&gid=36012&lang=en. Accessed 02/27, 2017.

(6) PAHO. Number of Reported Cases of Chikungunya Fever in the Americas, by Country or Territory. 2017; Available at: http://www.paho.org/hq/index.php?option=com_topics&view=readall&cid=5927&Itemid=40931&l21ang=en. Accessed 02/27, 2017.

(7) WHO. Global strategy for dengue prevention and control 2012-2020. 2012.

(8) Dom NC, Faiz Madzlan M, Nadira Yusoff SN, Hassan Ahmad A, Ismail R, Nazrina Camalxaman S. Profile distribution of juvenile *Aedes* species in an urban area of Malaysia. Trans R Soc Trop Med Hyg 2016 Apr;110(4):237-245.

(9) Khan J, Khan I, Amin I. A Comprehensive Entomological, Serological and Molecular Study of 2013 Dengue Outbreak of Swat, Khyber Pakhtunkhwa, Pakistan. PLoS One 2016 Feb 5;11(2):e0147416.

(10) Mboera LE, Mweya CN, Rumisha SF, Tungu PK, Stanley G, Makange MR, et al. The Risk of Dengue Virus Transmission in Dar es Salaam, Tanzania during an Epidemic Period of 2014. PLoS Negl Trop Dis 2016 Jan 26;10(1):e0004313.

(11) Dhar-Chowdhury P, Haque CE, Lindsay R, Hossain S. Socioeconomic and Ecological Factors Influencing *Aedes* aegypti Prevalence, Abundance, and Distribution in Dhaka, Bangladesh. Am J Trop Med Hyg 2016 Jun 1;94(6):1223-1233.

(12) WHO. Dengue: guidelines for diagnosis, treatment, prevention, and control. 2009.

(13) Bowman LR, Donegan S, McCall PJ. Is Dengue Vector Control Deficient in Effectiveness or Evidence?: Systematic Review and Meta-analysis. PLoS Negl Trop Dis 2016 Mar 17;10(3):e0004551.

(14) Paredes-Esquivel C, Lenhart A, del Rio R, Leza MM, Estrugo M, Chalco E, et al. The impact of indoor residual spraying of deltamethrin on dengue vector populations in the Peruvian Amazon. Acta Trop 2016 Feb;154:139-144.

(15) Vazquez-Prokopec GM, Kitron U, Montgomery B, Horne P, Ritchie SA. Quantifying the spatial dimension of dengue virus epidemic spread within a tropical urban environment. PLoS Negl Trop Dis 2010 Dec 21;4(12):e920.

(16) Lorono-Pino MA, Garcia-Rejon JE, Machain-Williams C, Gomez-Carro S, Nunez-Ayala G, Najera-Vazquez Mdel R, et al. Towards a Casa Segura: a consumer product study of the effect of insecticide-treated curtains on *Aedes aegypti* and dengue virus infections in the home. Am J Trop Med Hyg 2013 Aug;89(2):385-397.

(17) Al-Dubai SA, Ganasegeran K, Mohanad Rahman A, Alshagga MA, Saif-Ali R. Factors affecting dengue fever knowledge, attitudes and practices among selected urban, semi-urban and rural communities in Malaysia. Southeast Asian J Trop Med Public Health 2013 Jan;44(1):37-49.

(18) Alyousefi TA, Abdul-Ghani R, Mahdy MA, Al-Eryani SM, Al-Mekhlafi AM, Raja YA, et al. A household-based survey of knowledge, attitudes and practices towards dengue fever among local urban communities in Taiz Governorate, Yemen. BMC Infect Dis 2016 Oct 7;16(1):543.

(19) Castro M, Sanchez L, Perez D, Sebrango C, Shkedy Z, Van der Stuyft P. The relationship between economic status, knowledge on dengue, risk perceptions and practices. PLoS One 2013 Dec 12;8(12):e81875.

(20) Chandren JR, Wong LP, AbuBakar S. Practices of Dengue Fever Prevention and the Associated Factors among the Orang Asli in Peninsular Malaysia. PLoS Negl Trop Dis 2015 Aug 12;9(8):e0003954.

(21) Chanyasanha C, Guruge GR, Sujirarat D. Factors influencing preventive behaviors for dengue infection among housewives in Colombo, Sri Lanka. Asia Pac J Public Health 2015 Jan;27(1):96-104.

(22) Dhimal M, Aryal KK, Dhimal ML, Gautam I, Singh SP, Bhusal CL, et al. Knowledge, attitude and practice regarding dengue fever among the healthy population of highland and lowland communities in central Nepal. PLoS One 2014 Jul 9;9(7):e102028.

(23) Mayxay M, Cui W, Thammavong S, Khensakhou K, Vongxay V, Inthasoum L, et al. Dengue in peri-urban Pak-Ngum district, Vientiane capital of Laos: a community survey on knowledge, attitudes and practices. BMC Public Health 2013 May 3;13:434-2458-13-434.

(24) Naing C, Ren WY, Man CY, Fern KP, Qiqi C, Ning CN, et al. Awareness of dengue and practice of dengue control among the semi-urban community: a cross sectional survey. J Community Health 2011 Dec;36(6):1044-1049.

(25) Ramzan M, Ansar A, Nadeem S. Dengue Epidemics: Knowledge perhaps is the Only Key to Success. J Ayub Med Coll Abbottabad 2015 Apr-Jun;27(2):402-406.

(26) Saied KG, Al-Taiar A, Altaire A, Alqadsi A, Alariqi EF, Hassaan M. Knowledge, attitude and preventive practices regarding dengue fever in rural areas of Yemen. Int Health 2015 Nov;7(6):420-425.

(27) Sayavong C, Chompikul J, Wongsawass S, Rattanapan C. Knowledge, attitudes and preventive behaviors related to dengue vector breeding control measures among adults in communities of Vientiane, capital of the Lao PDR. J Infect Public Health 2015 Sep-Oct;8(5):466-473.

(28) Siddiqui TR, Ghazal S, Bibi S, Ahmed W, Sajjad SF. Use of the Health Belief Model for the Assessment of Public Knowledge and Household Preventive Practices in Karachi, Pakistan, a Dengue-Endemic City. PLoS Negl Trop Dis 2016 Nov 10;10(11):e0005129.

(29) Park W, Lloyd L. Planning social mobilization and communication for dengue fever prevention and control: a step-by-step guide. 2004.

(30) Alves AC, Fabbro AL, Passos AD, Carneiro AF, Jorge TM, Martinez EZ. Knowledge and practices related to dengue and its vector: a community-based study from Southeast Brazil. Rev Soc Bras Med Trop 2016 Apr;49(2):222-226.

(31) Garcia-Betancourt T, Higuera-Mendieta DR, Gonzalez-Uribe C, Cortes S, Quintero J. Understanding Water Storage Practices of Urban Residents of an Endemic Dengue Area in Colombia: Perceptions, Rationale and Socio-Demographic Characteristics. PLoS One 2015 Jun 10;10(6):e0129054.

(32) Paz-Soldan VA, Bauer K, Morrison AC, Cordova Lopez JJ, Izumi K, Scott TW, et al. Factors Associated with Correct and Consistent Insecticide Treated Curtain Use in Iquitos, Peru. PLoS Negl Trop Dis 2016 Mar 11;10(3):e0004409.

(33) Paz-Soldan VA, Morrison AC, Cordova Lopez JJ, Lenhart A, Scott TW, Elder JP, et al. Dengue Knowledge and Preventive Practices in Iquitos, Peru. Am J Trop Med Hyg 2015 Dec;93(6):1330-1337.

(34) Syed M, Saleem T, Syeda UR, Habib M, Zahid R, Bashir A, et al. Knowledge, attitudes and practices regarding dengue fever among adults of high and low socioeconomic groups. J Pak Med Assoc 2010 Mar;60(3):243-247.

(35) Wong LP, Shakir SM, Atefi N, AbuBakar S. Factors affecting dengue prevention practices: nationwide survey of the Malaysian public. PLoS One 2015 Apr 2;10(4):e0122890.

(36) Ong DQ, Sitaram N, Rajakulendran M, Koh GC, Seow AL, Ong ES, et al. Knowledge and practice of household mosquito breeding control measures between a dengue hotspot and non-hotspot in Singapore. Ann Acad Med Singapore 2010 Feb;39(2):146-149.

(37) Wong LP, AbuBakar S, Chinna K. Community knowledge, health beliefs, practices and experiences related to dengue fever and its association with IgG seropositivity. PLoS Negl Trop Dis 2014 May 22;8(5):e2789.

(38) Arellano C, Castro L, Diaz-Caravantes RE, Ernst KC, Hayden M, Reyes-Castro P. Knowledge and Beliefs about Dengue Transmission and Their Relationship with Prevention Practices in Hermosillo, Sonora. Front Public Health 2015 Jun 3;3:142.

(39) Chen B, Yang J, Luo L, Yang Z, Liu Q. Who Is Vulnerable to Dengue Fever? A Community Survey of the 2014 Outbreak in Guangzhou, China. Int J Environ Res Public Health 2016 Jul 14;13(7):10.3390/ijerph13070712.

(40) Demanou M, Pouillot R, Grandadam M, Boisier P, Kamgang B, Herve JP, et al. Evidence of dengue virus transmission and factors associated with the presence of anti-dengue virus antibodies in humans in three major towns in Cameroon. PLoS Negl Trop Dis 2014 Jul 10;8(7):e2950.

(41) Garg S, Chakravarti A, Singh R, Masthi NR, Goyal RC, Jammy GR, et al. Dengue serotype-specific seroprevalence among 5- to 10-year-old children in India: a community-based cross-sectional study. Int J Infect Dis 2016 Nov 4;54:25-30.

(42) Ramos MM, Mohammed H, Zielinski-Gutierrez E, Hayden MH, Lopez JL, Fournier M, et al. Epidemic dengue and dengue hemorrhagic fever at the Texas-Mexico border: results of a household-based seroepidemiologic survey, December 2005. Am J Trop Med Hyg 2008 Mar;78(3):364-369.

(43) Soghaier MA, Himatt S, Osman KE, Okoued SI, Seidahmed OE, Beatty ME, et al. Cross-sectional community-based study of the socio-demographic factors associated with the prevalence of dengue in the eastern part of Sudan in 2011. BMC Public Health 2015 Jun 18;15:558-015-1913-0.

(44) Messenger AM, Barr KL, Weppelmann TA, Barnes AN, Anderson BD, Okech BA, et al. Serological evidence of ongoing transmission of dengue virus in permanent residents of Key West, Florida. Vector Borne Zoonotic Dis 2014 Nov;14(11):783-787.

(45) PAHO. The number of reported cases of dengue and severe dengue (DS) in the Americas by country (1995-2015). 2017; Available at: www.who.int/denguenet, 2017.

(46) Stewart Ibarra A, Kenneson A, King CA, Abbott M, Barbachano-Guerrero A, Beltrán-Ayala E, et al. The high burden of dengue and chikungunya in southern coastal Ecuador: Epidemiology and phylogenetics from a prospective study in Machala in 2014-2015. Preprint. Available from: bioarXiv. doi: https://doi.org/10.1101/102004.

(47) Stewart-Ibarra AM, Munoz AG, Ryan SJ, Ayala EB, Borbor-Cordova MJ, Finkelstein JL, et al. Spatiotemporal clustering, climate periodicity, and social-ecological risk factors for dengue during an outbreak in Machala, Ecuador, in 2010. BMC Infect Dis 2014 Nov 25;14:610-014-0610-4.

(48) Stewart Ibarra AM, Ryan SJ, Beltran E, Mejia R, Silva M, Munoz A. Dengue vector dynamics (*Aedes aegypti*) influenced by climate and social factors in Ecuador: implications for targeted control. PLoS One 2013 Nov 12;8(11):e78263.

(49) Handel A, Beltran E, Borbor Cordova MJ, Fessler A, Finkelstein J, Robalino R, et al. Knowledge, attitudes, and practices regarding dengue infection among public sector healthcare providers in Machala, Ecuador. Tropical Diseases, Travel Medicine and Vaccines 2016;2:8.

(50) Stewart Ibarra AM, Luzadis VA, Borbor Cordova MJ, Silva M, Ordonez T, Beltran Ayala E, et al. A social-ecological analysis of community perceptions of dengue fever and *Aedes aegypti* in Machala, Ecuador. BMC Public Health 2014 Nov 4;14:1135-2458-14-1135.

(51) Heydari N, Larsen DA, Neira M, Beltran Ayala E, Fernandez P, Adrian J, et al. Household Dengue Prevention Interventions, Expenditures, and Barriers to *Aedes aegypti* Control in Machala, Ecuador. Int J Environ Res Public Health 2017 Feb 16;14(2):10.3390/ijerph14020196.

(52) Camargo S. History of *Aedes aegypti* eradication in the Americas. Bull World Health Organ 1967;36(4):602-603.

(53) Brathwaite Dick O, San Martin JL, Montoya RH, del Diego J, Zambrano B, Dayan GH. The history of dengue outbreaks in the Americas. Am J Trop Med Hyg 2012 Oct;87(4):584-593.

(54) Centers for Disease Control (CDC). Dengue epidemic--Ecuador, 1988. MMWR Morb Mortal Wkly Rep 1989 Jun 23;38(24):419-421.

(55) Alava A, Mosquera C, Vargas W, Real J. Dengue en el Ecuador 1989–2002. Revista Ecuatoriana de Higiene y Medicina Tropical 2005;42:11-34.

(56) Real J, Mosquera C. Deteccion del virus dengue en el Ecuador. Una vision epidemiologica periodo 1988–2012. 2012.

(57) Thomas SJ, Aldstadt J, Jarman RG, Buddhari D, Yoon IK, Richardson JH, et al. Improving dengue virus capture rates in humans and vectors in Kamphaeng Phet Province, Thailand, using an enhanced spatiotemporal surveillance strategy. Am J Trop Med Hyg 2015 Jul;93(1):24-32.

(58) Manrique-Saide P, Davies CR, Coleman PG, Che-Mendoza A, Dzul-Manzanilla F, Barrera-Perez M, et al. The risk of *Aedes aegypti* breeding and premises condition in South Mexico. J Am Mosq Control Assoc 2013 Dec;29(4):337-345.

(59) Vontas J, Kioulos E, Pavlidi N, Morou E, della Torre A, Ranson H. Insecticide resistance in the madjor dengue vectors *Aedes albopictus* and *Aedes aegypti*, Pesticide Biochemistry and Physiology 2012;104(2):126-131.

(60) Bowman LR, Donegan S, McCall PJ. Is Dengue Vector Control Deficient in Effectiveness or Evidence?: Systematic Review and Meta-analysis. PLoS Negl Trop Dis 2016 Mar 17;10(3):e0004551.

(61) Trpis M, McClelland GA, Gillett JD, Teesdale C, Rao TR. Diel periodicity in the landing of *Aedes aegypti* on man. Bull World Health Organ 1973 May;48(5):623-629.

(62) Lorono-Pino MA, Garcia-Rejon JE, Machain-Williams C, Gomez-Carro S, Nunez-Ayala G, Najera-Vazquez Mdel R, et al. Towards a Casa Segura: a consumer product study of the effect of insecticide-treated curtains on *Aedes aegypti* and dengue virus infections in the home. Am J Trop Med Hyg 2013 Aug;89(2):385-397.

(63) Tun-Lin W, Lenhart A, Nam VS, Rebollar-Tellez E, Morrison AC, Barbazan P, et al. Reducing costs and operational constraints of dengue vector control by targeting productive breeding places: a multi-country non-inferiority cluster randomized trial. Trop Med Int Health 2009 Sep;14(9):1143-1153.

(64) Tun-Lin W, Kay BH, Barnes A. The Premise Condition Index: a tool for streamlining surveys of *Aedes aegypti*. Am J Trop Med Hyg 1995 Dec;53(6):591-594.

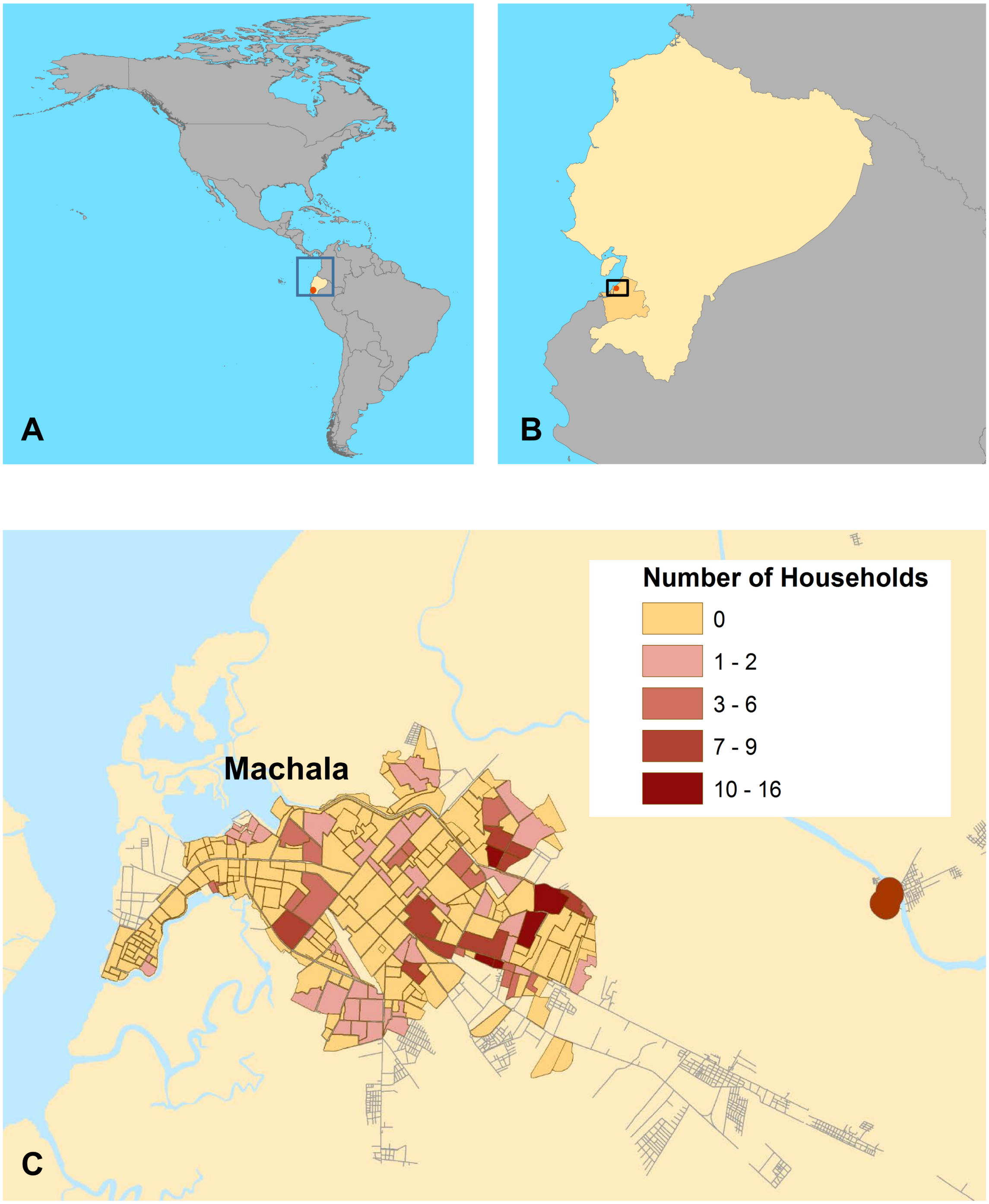

Figure 1. A map of the study site and distribution of study households. (A) location of Ecuador in the Americas (B) location of the city of Machala, El Oro Province, Ecuador (C) the distribution of households surveyed in this study. Household locations were aggregated to the neighborhood level for de-identification. Some clusters (5 households) have been disaggregated across block boundaries.

Table 1: Social-ecological factors in households with versus without acute or recent dengue infections.

	All households N=219	Households without dengue N=80	Households with dengue N=139	p-value
Head of Household Characteristics				
Age - mean (SD)	47.8 (13.6)	50.3 (14.7)	46.3 (12.8)	**0.0403**
Sex – female	53/219 (24.2%)	36/80 (32.5%)	27/139 (19.4%)	**0.0296**
Education – secondary or more	128/215 (59.5%)	47/78 (60.3%)	81/137 (59.1%)	0.8708
Employed	182/219 (83.1%)	59/80 (73.8%)	123/139 (88.5%)	**0.0051**
If employed, make more than minimum wage	74/165 (44.9%)	24/52 (46.2%)	50/113 (44.2%)	0.8231
If employed, employment is stable	132/12 (72.5%)	43/59 (72.9%)	89/123 (72.4%)	0.9410
Household Characteristics				
# People in household - mean (SD)	4.57 (1.90)	4.29 (1.86)	4.73 (1.91)	0.0999
# bedrooms - mean (SD)	2.53 (1.06)	2.49 (1.10)	2.55 (1.04)	0.6726
#People per bedroom - mean (SD)	2.12 (1.32)	2.02 (1.32)	2.18 (1.32)	0.3926
# families on property – mean (SD)	1.40 (0.88)	1.40 (1.04)	1.40 (0.78)	0.9815
Rented	38/219 (17.4%)	11/80 (13.8%)	27/139 (19.4%)	0.2856
Other renters on property	23/219 (10.5%)	10/80 (12.5%)	13/139 (9.35%)	0.4644
Condition of patio				
No patio	44/218 (20.2%)	16/80 (20.0%)	28/138 (20.3%)	
Disorganized	34/218 (15.6%)	9/80 (11.2%)	25/138 (18.1%)	
Average	106/218 (48.6%)	41/80 (51.2%)	65/138 (47.1%)	
Very organized/clean	34/218 (15.6%)	14/80 (17.5%)	20/138 (14.5%)	0.5712
Shade on patio				
No patio	44/218 (20.2%)	16/80 (20.0%)	28/138 (20.3%)	
Sunny (<25% shade)	50/218 (40.8%)	39/80 (48.8%)	50/138 (36.2%)	
Partial (25-50% shade)	35/218 (26.2%)	32/80 (27.5%)	35/138 (25.4%)	
Shaded (>50% shade)	25/218 (12.8%)	3/80 (3.75%)	25/138 (18.1%)	**0.0172**
Screens on all windows	63/219 (28.8%)	22/80 (27.5%)	41/139 (29.5%)	0.7533
Screens have no holes	58/98 (51.0%)	22/37 (59.5%)	28/61 (45.9%)	0.1931
Standing water present	94/217 (43.3%)	35/79 (44.3%)	59/138 (42.8%)	0.8245
Standing water in trash bins	30/219 (13.7%)	10/80 (12.5%)	30/139 (14.4%)	0.6955
Standing water in 55 gallon drums	49/219 (21.4%)	17/80 (21.2%)	32/139 (23.0%)	0.7620
Standing water in puddles	33/219 (15.1%)	11/80 (13.8%)	22/139 (15.8%)	0.6790
Standing water in tires	9/219 (4.11%)	4/80 (5.00%)	5/139 (3.60%)	0.7271
Abandoned property nearby	69/217 (31.8%)	18/79 (22.8%)	51/138 (37.0%)	**0.0310**
Services				

Piped water inside house	166/219 (75.8%)	68/80 (85.0%)	98/139 (70.5%)	**0.0159**
Always running water	110/218 (50.5%)	36/80 (45.0%)	74/138 (53.6%)	0.2197
Air conditioning	23/219 (10.5%)	10/80 (12.5%)	13/139 (9.35%)	0.4644
Cistern or elevated tank	160/219 (73.1%)	60/80 (75.0%)	100/139 (72.0%)	0.6234
Other water storage	95/219 (43.4%)	36/80 (45.0%)	59 /139 (42.4%)	0.7135
Sewage services	187/219 (85.4%)	72/80 (90.0%)	115/139 (82.7%)	0.1427
Trash picked up daily	54/219 (24.6%)	26/80 (32.5%)	28/139 (20.0%)	**0.0411**

Table 2. KAPs in households with versus without acute or recent dengue infections.

	All households N=219	Households without dengue N=80	Households with dengue N=139	p-value
Knowledge and Attitudes				
Considers dengue to be a serious problem in the community.	196/218 (89.9%)	69/180 (86.2%)	127/138 (92.0%)	0.1722
Believes dengue is a severe disease.	197/219 (89.9%)	69/80 (86.2%)	128/139 (92.1%)	0.1665
Believes dengue prevention in the household is difficult or impossible.	53/218 (24.3%)	23/79 (29.1%)	30/139 (21.6%)	0.2127
Knows that dengue is transmitted by mosquitoes.	197/218 (90.8%)	70/80 (87.5%)	127/137 (92.7%)	0.2013
Knows breeding location of mosquitoes.	212/218 (96.8%)	79/80 (98.8%)	133/139 (95.7%)	0.2141
Believes that lack of information is a barrier to prevention	39/219 (17.8%)	10/80 (12.5%)	29/139 (20.9%)	0.1193
Believes that cost is a barrier to prevention	15/219 (6.85%)	6/80 (7.50%)	9/139 (6.47%)	0.7724
Believes that lack of time is a barrier to prevention	20/219 (9.13%)	7/80 (8.75%)	13/139 (9.35%)	0.8815
Believes that too many mosquitoes is a barrier to prevention	39/219 (17.8%)	13/80 (16.2%)	26/139 (18.7%)	0.6475
Reports no barriers to prevention	119/219 (54.3%)	48/80 (60.0%)	71/139 (51.1%)	0.2019
Prevention Actions Taken				
Screens on windows/doors	22/219 (10.0%)	7/80 (8.75%)	15/139 (10.8%)	0.6285
Apply repellent	22/219 (10.0%)	10/80 (8.63%)	12/139 (12.5%)	0.3593
Clean garbage	81/219 (37.0%)	28/80 (35.0%)	53/139 (38.1%)	0.6441
Burn palosanto	11/219 (5.02%)	6/80 (7.50%)	5/139 (3.60%)	0.2029
Cover water containers	83/219 (37.9%)	24/80 (30.0%)	59/139 (42.4%)	0.0675
Shut windows/doors	21/219 (9.59%)	9/80 (11.2%)	12/139 (8.63%)	0.5265
Cut vegetation	3/219 (1.37%)	0/80 (0%)	3/139 (2.16%)	0.1858
Apply chemicals to standing water	56/219 (25.6%)	13/80 (16.2%)	43/139 (30.9%)	**0.0165**
Eliminate standing water	83/219 (37.9%)	25/80 (31.2%)	58/139 (41.7%)	0.1238
Pour diesel on the floors/puddles	2/219 (0.91%)	1/80 (1.25%)	1/139 (0.72%)	0.6910
Fumigate in my house	83/219 (37.9%)	45/80 (56.2%)	38/139 (27.3%)	**<0.0001**
Use mosquito net	45/219 (20.6%)	21/80 (26.2%)	24/139 (17.3%)	0.1131

Table 3. Multivariate logistic regression model of predictors of acute or recent dengue infections in the household.

Analysis of Maximum Likelihood Estimates						
Parameter	**DF**	**Estimate**	**SE**	**Wald Chi-Square**	**Pr > ChiSq**	**OR (95%CI)**
Model 1: Main Effects						
Intercept	1	-1.5256	0.5209	8.5780	0.0034	
Abandoned property nearby	1	0.5292	0.2386	4.9191	0.0266	2.882 (1.131-7.342)
Frequent interruptions in water supply	1	0.4542	0.2110	4.6341	0.0313	2.480 (1.085-5.672)
Piped water inside the house	1	-0.9461	0.2912	10.5543	0.0012	0.151 (0.048-0.472)
Patio with >50% shade	1	1.3929	0.4318	10.4046	0.0013	16.213 (2.983-88.108)
Fumigation inside house	1	-0.7358	0.2102	12.2566	0.0005	0.230 (0.101-0.523)
Use mosquito nets	1	-0.5192	0.2540	4.1790	0.0409	0.354 (0.131-0.958)
Cost is a barrier	1	-0.8624	0.4392	3.8565	0.0496	0.178 (0.032-0.997)
Model 2: Main Effects and Two-way Interactions						
Intercept	1	1.2075	0.4201	8.2636	0.004	
Abandoned property nearby	1	0.3443	0.4495	0.5868	0.4437	
Piped water inside house	1	-0.2848	0.4643	0.3763	0.5396	
Patio with >50% shade	1	2.5854	0.7196	12.9066	0.0003	13.268 (3.238-54.373)
Fumigation inside house	1	0.3292	0.9075	0.1316	0.7168	
Use mosquito nets	1	-0.9427	0.4008	5.5337	0.0187	0.390 (0.178-0.854)
Abandoned property*fumigation	1	1.4994	0.7442	4.0596	0.0439	
Piped water inside*fumigation	1	-2.5311	0.9907	6.5277	0.0106