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Source Reduction Behavior as an Independent Measurement of the Impact of a Public Health Education Campaign in an Integrated Vector Management Program for the Asian Tiger Mosquito

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Abstract: The goal of this study was to evaluate the effectiveness of a public health educational campaign to reduce backyard mosquito-larval habitats. Three communities each, within two New Jersey counties, were randomly selected to receive: (1) both education and mosquito control, (2) education only, and (3) no education or mosquito control. Four separate educational events included a 5-day elementary school curriculum in the spring, and three door to door distributions of educational brochures. Before and after

each educational event, the numbers of mosquito-larval container habitats were counted in 50 randomly selected homes per study area. Container surveys allowed us to measure source reduction behavior. Although we saw reductions in container habitats in sites receiving education, they were not significantly different from the control. Our results suggest that traditional passive means of public education, which were often considered the gold standard for mosquito control programs, are not sufficient to motivate residents to reduce backyard mosquito-larval habitats.

Keywords: Asian tiger mosquito; *Aedes albopictus*; public health education; source reduction

1. Introduction

Container-inhabiting mosquitoes are a large focus of public education and outreach, as they are serious nuisance pests and vectors of disease-causing pathogens to humans. Because these mosquitoes deposit eggs in backyard containers, control of mosquito larvae over large areas is often difficult, primarily due to lack of access and available resources. Community participation is an important aspect in the control of container-inhabiting mosquitoes, and can involve source reduction by disposal of unwanted habitats, by turning over containers that hold water, or by covering permanent water collectors [1]. Community participation is an essential and cost-effective means of reducing container mosquitoes but requires community ownership to achieve sustainability [2]. Source reduction can greatly affect the distribution of mosquito larvae in a neighborhood [3], by limiting the number of available habitats for ovipositing mosquitoes. However, certain container habitats, such as bird baths, tarpaulins, and plant pot receptacles are difficult to eliminate and can continue to be potential oviposition sites for mosquitoes [3]. Therefore, public education campaigns can have beneficial effects on vector control within those communities [4], by teaching and motivating the public on how to manage these types of habitats in order to prevent immature mosquitoes from completing their development to the adult biting stage.

Container inhabiting mosquitoes are both cosmopolitan species and important vectors of disease. In the northeastern United States, the principal vector of West Nile virus (WNV) is *Culex pipiens* L. [5]. This species feeds primarily on birds, but also takes blood meals from humans [6], and can be an important bridge vector. *Culex pipiens* is closely associated with humans, ovipositing eggs in septic tanks, storm drains, and artificial containers [7]. In New Jersey, anthropophilic container-inhabiting species, such as *Aedes albopictus* (Skuse), *Ae. triseriatus* (Say), and *Ae. japonicus* (Theobald) are infected for WNV annually. *Aedes japonicus* readily feeds on both avian and mammalian hosts in its native range [8], and has been shown to be a competent vector for Eastern Equine Encephalitis (EEE) [9]. Although *Ae. japonicus* was first detected in the United States in 1998, it rapidly spread into each state in the Northeast. *Aedes albopictus*, another invasive species, is limited in distribution by daily winter temperatures [10], and is capable of acquiring and transmitting EEE virus in the laboratory, in addition to some 29 other arthropod-borne viruses [11]. Both *Ae. albopictus* and *Ae. japonicus* readily deposit eggs in artificial and natural containers. Therefore,

peridomestic container-inhabiting mosquitoes pose a great public health risk, by serving as vectors of disease-causing pathogens.

The goal of this study was to examine the effectiveness of a public health education campaign to reduce mosquito-inhabiting containers in backyards, using a longitudinal study design, by counting suitable containers before and after educational events.

2. Methods

2.1. Site Selection

Two study regions in New Jersey were selected as part of a larger area-wide effort to control the Asian tiger mosquito, *Aedes albopictus* [12]. These included the Raritan Bayshore region of Monmouth County, and the urban city of Trenton, in Mercer County. Both regions included three study sites (approximately 1,000 homes each), which were found to be similar in demographics, socio-economics, parcel sizes, and *Ae. albopictus* populations. In each county, the sites were randomly placed into one of two treatments or a control including one site receiving routine mosquito control and educational activities (full intervention), one site receiving educational activities only (education only), and a third site that served as an untreated control (no intervention).

2.2. Novel Educational Activities

At the four sites receiving the educational activities, the following interventions were performed: a 5-day elementary school curriculum geared toward 3rd through 5th graders was developed, and presented to students by their teachers. Each component of the curriculum adhered to New Jersey state science curriculum standards for that particular age group, and included information about mosquito lifecycles, food chains, biology, problem solving, and classification. Each component consisted of a lecture, hands on activity, and assignment. Teachers were given the materials, instructed how to present the lessons, and performed the lessons in their own classrooms. Teachers in 45 classes received the materials in the four study sites. Average class sizes were 20 students in Monmouth and 24 in Mercer. For a summer project, the children were given a take-home ovitrap to collect mosquito eggs, with instructions on how to count eggs, and how to upload their data to an Internet site created for this purpose. Children were given a secret access code to upload data. Once on the site, they could play ten different computer games relating to mosquitoes. The goal of the summer ovitrap project was to bring the public back to the educational website to reinforce learning concepts on source reduction of mosquito-producing container habitats.

For adult education, four different educational brochures were developed and distributed over the course of the spring and summer. These included brochures on: (1) spring cleanup, (2) quick guide to reducing biting mosquitoes, (3) the Asian tiger mosquito, and (4) canine heartworm. The brochures were developed with the aid of focus groups and surveys of residents in our target communities. The goal was to develop easy to follow instructions on source reduction in both English and Spanish. All materials provided links to our educational website, where the public could find additional brochures on the Asian tiger mosquito, videos of mosquitoes and source reduction, maps tracking the distribution

of the Asian tiger mosquito, kids' pages with games and activities, and a weekly blog. Brochures were distributed using volunteers to hang brochures on door knobs.

2.3. Container Surveys

Source reduction behavior was evaluated by conducting container surveys in each of the six study sites, where 50 homes were randomly selected to serve as our survey locations. Homes were selected using Geographic Information System (GIS) technology, using grids to separate out the study area into 50 zones. The home closest to the center of each grid, when permission was granted, was selected as our survey location. Surveys were conducted on four occasions (before and after each educational event). A minimum of six teams of two were sent to conduct the surveys over a two day period. All study areas were sampled at the same time, to eliminate any confounders, such as day in week, or precipitation events. During each survey, the number of containers (anything natural or manmade whose shape and structure allows it to collect and hold water for 2 or more days), wet containers (holding any amount of water), mosquito larvae positive containers, and mosquito pupae positive containers were counted. The type of container was also recorded, along with whether or not it was moveable (*i.e.*, could a 5 year-old child move the container), and whether or not it was disposable (*i.e.*, unusable or unwanted by homeowner).

2.4. Statistical Analysis

For temporal comparison of study sites, repeated measures Analysis of Variance (ANOVA) was conducted using SPSS. To ensure that homeowners in the analysis were as similar as possible, only those property parcels meeting certain criteria were included. These criteria included similar mean parcel sizes (4,000–6,000 ft² [372–557 m²] for Monmouth County, and 1,500–3,500 ft² [139–325 m²] for Mercer County), and parcel locations (that were surrounded on three sides by homes). For spatial analysis, monthly surveys were plotted using ArcMAP GIS (North American Datum 1983). For each site and month, maps were created using inverse distance weighted mapping tools. Maps were standardized to the same scale, and compared by looking at overall trends in the dataset. A Moran's I test was used to determine if clusters of source reduction behavior overlapped with demographic variables.

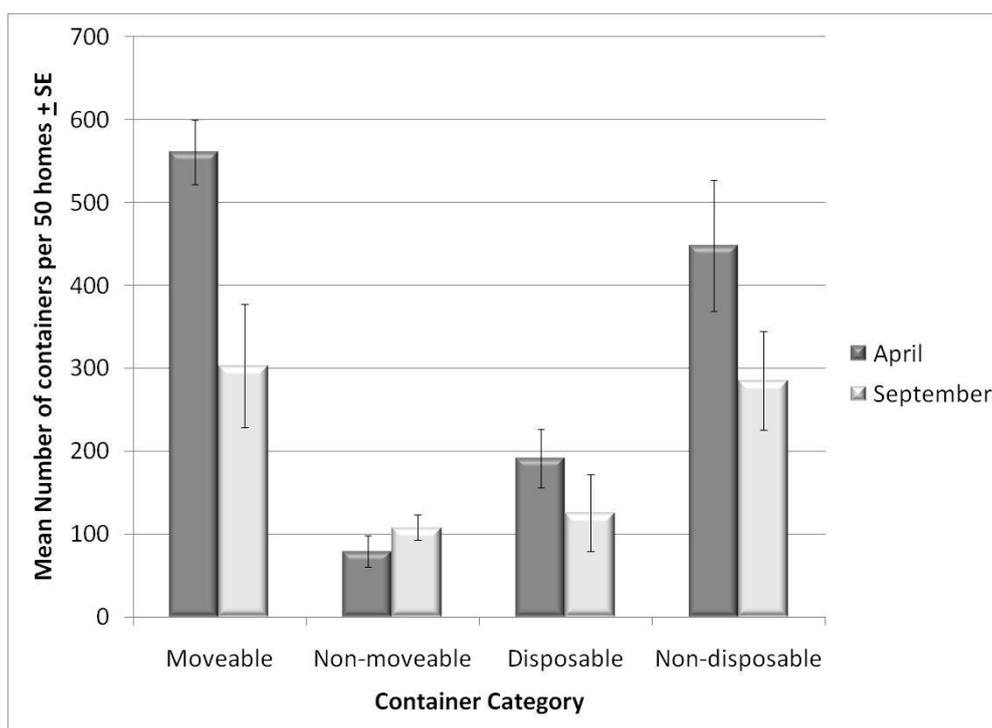
3. Results

Our educational efforts were implemented in two study sites in each of the two counties. A third site in each county did not receive any education, and served as a control. In our first year of education, there were 45 elementary school classes, in nine schools, for a total of 1,125 students that received the educational materials. In addition, over 24,000 brochures were distributed over a six month period to over 6,000 homes.

A total of 300 homes were surveyed on four separate occasions from April to October of 2009. During that time, a total of 11,672 containers were counted in Monmouth (45.8%) and Mercer (54.2%) counties. Most of these containers were trash cans (20.1%), buckets (15.9%), plant receptacles (10.2%), toys (6.2%), plastic bags (5.7%), and tarpaulins (5.1%).

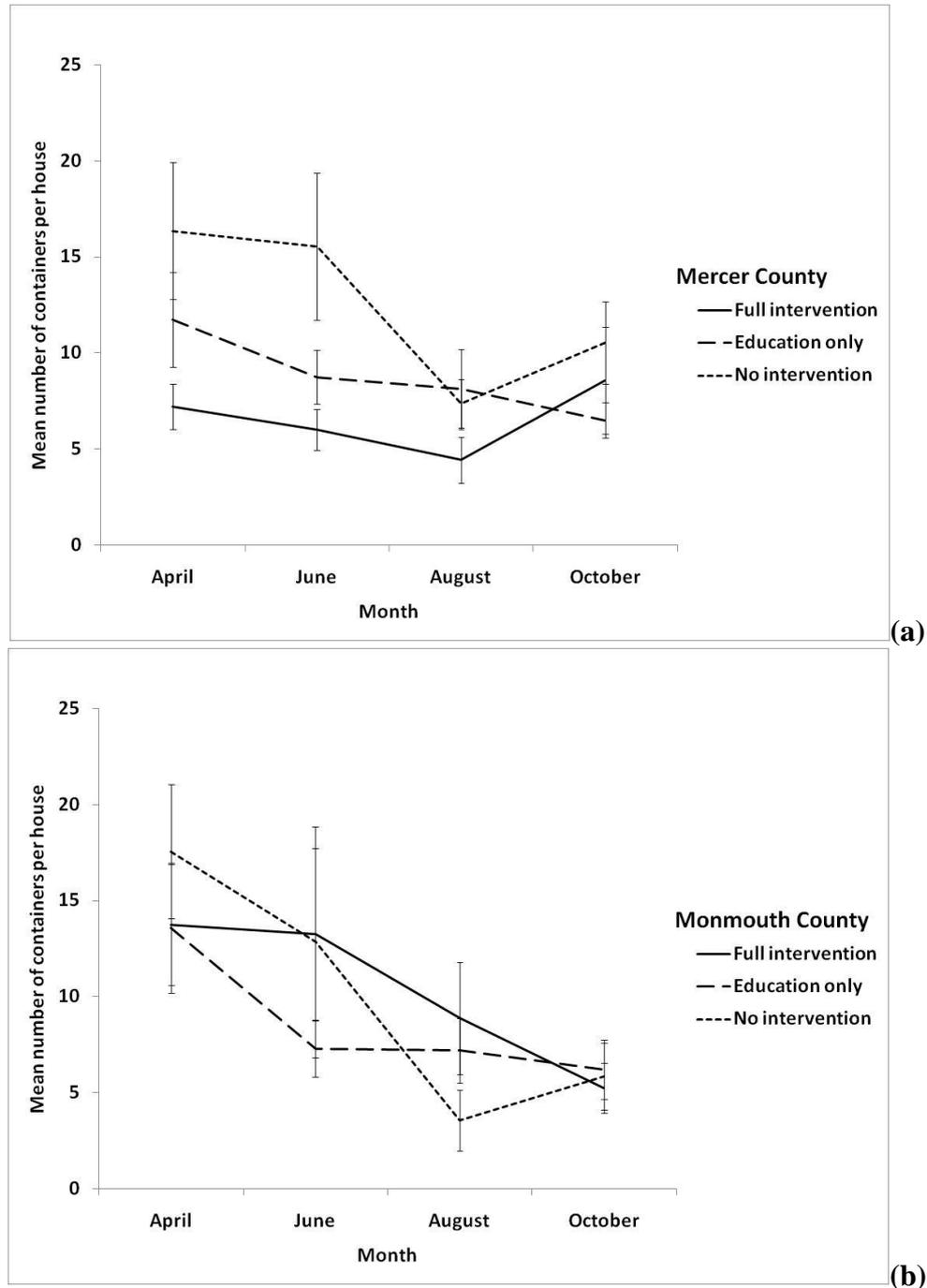
Before educational interventions were performed, the highest percentages of containers in backyards were categorized as non-disposable and moveable (Figure 1). Examples of these types of containers included trashcans (31.8%), buckets (16.7%), planters and plant dishes (11.2%), and toys (10%). The second most abundant container type were those that were both disposable and moveable, such as bottles and cans (35.9%), and plastic bags (18.3%). There were few containers that were both non-moveable and non-disposable, such as large planters (11.4%), bird baths (10%), and children's pools (6%). Lastly, the fewest containers were found in the category for disposable and non-moveable, such as filled trash bags (38.8%), and appliances (4%). We found the largest reductions in containers that were moveable ($F = 9.36$, $P = 0.012$), compared to those that were non-moveable ($F = 1.37$, $P = 0.269$), disposable ($F = 1.28$, $P = 0.284$), and non-disposable ($F = 2.7$, $P = 0.130$).

Figure 1. Change in the number of containers found in 2009, by container type. Disposable containers are defined as those that no longer serve a purpose and/or are unwanted by the homeowner. Moveable containers are defined as being able to be moved by a 5-year old child. Differences in containers are between the first (April) and last (September) container surveys. Data is represented as mean number of containers per 50 homes \pm the standard error.



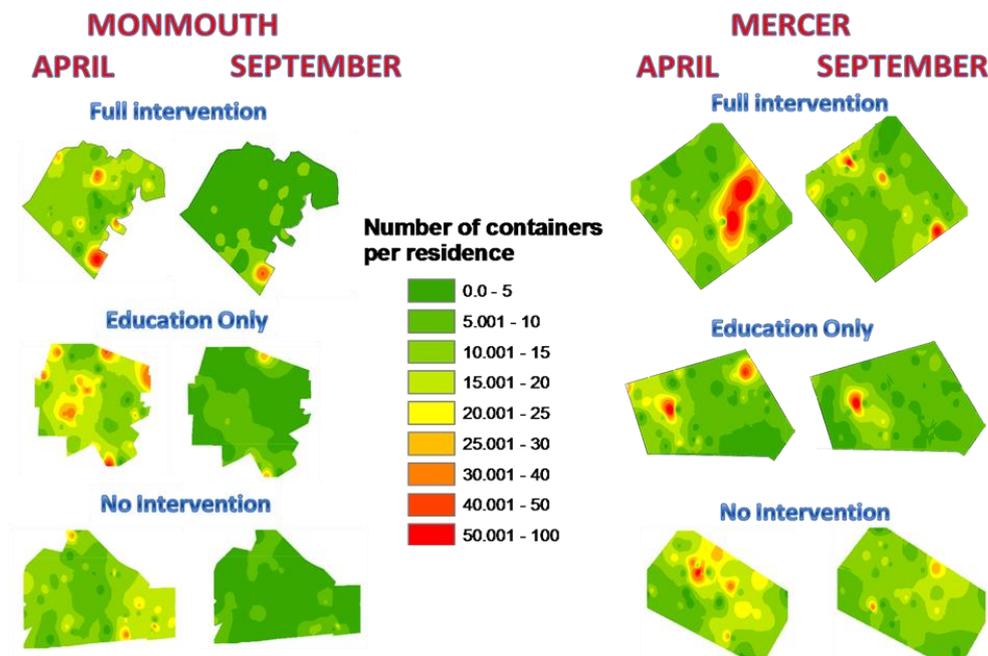
Repeated measures analysis showed that there were no significant differences in source reduction behavior for those individuals receiving education, and those not receiving education ($P = 0.474$) in Mercer county (Figure 2). However, there was a significant difference in source reduction behavior in those receiving education in the Monmouth county site ($P = 0.012$).

Figure 2. Monthly mean number of containers per home found in (a) Mercer and (b) Monmouth counties, 2009. For each county, the full intervention site is represented by a solid line. The education only sites are represented by long dashes, and the control sites (no intervention) are represented by short dashes.



Spatial analysis allowed us to examine particular demographic areas in each site that were unwilling to exhibit source reduction behavior (Figure 3). An examination of before and after maps, showed that all sites, regardless of receiving education, showed some degree of source reduction.

Figure 3. Spatial analysis of sites before and after educational interventions. Maps indicate the number of containers per home. For each county and site, the map on the left indicates survey results done before any intervention (April). The maps on the left indicate the survey results at the end of the season (September).



When examining demographic variables, we found there were significant clusters for source reduction behavior (Moran's $I = 0.14$, $Z = 13.2$), renter occupied homes (Moran's $I = 0.08$, $Z = 4.67$), and vacant homes (Moran's $I = 0.05$, $Z = 3.5$) in the Mercer education only site, and for source reduction behavior (Moran's $I = 0.07$, $Z = 7.89$), and renter occupied homes (Moran's $I = 0.05$, $Z = 4.32$) in the Monmouth education only site. However, the demographic and behavior clusters did not overlap ($X^2 = 0.1$, $P = 0.76$) in either site. In the Mercer county site, the areas that continued to have high numbers of containers were located in census tracts that had slightly higher median income levels (\$36,201) than sites more willing to change (\$35,327).

4. Discussion

The goal of our study was to determine if our mosquito education program initiated a behavioral change in residents, by motivating them to perform source reduction of mosquito habitats in their backyards. In the education only sites, there was a decrease from 16.3 containers per home (Monmouth) and 10.2 containers per home (Mercer) in April to 5.5 (Monmouth) and 8.8 (Mercer) containers per home in September. Although this drop suggests our efforts might have been effective, we noticed the same drop in containers per house in sites that did not receive education, resulting in sites that were not statistically different. It is possible that the presence of mosquito personnel counting containers in all sites could have indirectly motivated residents to conduct source reduction behavior in their backyards. Mosquito personnel were instructed not to educate homeowners in the control sites. This may have raised concerns with residents, who might be worried about being cited or fined as a result of producing mosquitoes in their backyard. Another factor that may have contributed to the decline in all

sites is that our first survey was conducted in the spring when the weather is much cooler. At this time, homeowners were likely in the early stages of spring cleaning, and had not yet prepared their yards for the summer. This observation was supported by the types of containers that were counted during each month. During the April survey, the most frequently encountered containers were small buckets and trashcans. In the following month, the most abundant containers were plant receptacles and buckets. In the summer, wheel barrows and children's pools replaced cans and bottles as part of the top ten container types counted.

The primary means of educating the public in this study was by using various educational pamphlets. A study by Schreiber and Morris [13], found that color brochures were more effective at conveying the message. The authors found that providing black and white brochures was similar to providing no literature at all. In order for us to optimize our pamphlets to best reach the community, we conducted a focus group and survey, which contained residents of the target audience. Pamphlets were provided in both English and Spanish, in full color along with photographs. While our materials were designed with every attempt to appeal to the target audience, this method of education might be too passive in motivating the public to implement effective source reduction measures. Schreiber and Cuda [14] compared the effectiveness of brochures in three socio-economic regions. Although the low income region showed some degree of source reduction behavior, the pamphlets were ineffective in encouraging middle and high income home owners to take recommended action. Instead of relying on these passive forms of education, our future educational efforts will rely on more active community-based approaches to education, since the most effective education campaigns are one's where the community has ownership in the program [2]. These will involve the use of community peer educators to empower residents to reduce mosquito habitats.

The largest container reductions recorded were categorized as moveable containers. Although the number of disposable containers did not decrease significantly as a whole, we saw the largest decrease in disposable containers in the full intervention sites. A reason for this was that mosquito control agencies were performing door to door cleanups of every house in the community. Therefore, we expected to see a decrease in disposable containers in these sites. However, we did not see a decrease in the education only or no intervention control sites. Richards *et al.* [3] showed that in neighborhoods where source reduction was achieved, mosquito oviposition shifted to container types that were difficult to remove, such as tarpaulins and plant pot receptacles. We noticed a similar shift in the Monmouth County full intervention site, where 87.5% of the larvae at the end of the season were found in non-moveable containers.

We found that those residents unwilling to implement source reduction, as indicated by lack of reduction in number of containers, were clustered in both study areas. However, we were unable to find a demographic variable that showed the same pattern of clustering. Before conducting the study, a demographic analysis was conducted in each county to document that all three study sites were similar for mean parcel sizes, income, education, and poverty level. In addition, all three sites were chosen because they had very little variation in the demographics within the site.

Although we were not directly comparing Monmouth and Mercer county sites, we did observe a more dramatic reduction (66.3%) in the suburban Monmouth County, compared to the highly urbanized (13.7%) Mercer county site. During the 2000 census, the Monmouth county site reported a

median income of \$54,954 per year, compared to Mercer county site's median income of \$35,764 per year. In Houston, Texas, Rios *et al.* [15] showed that there are higher numbers of containers in communities with less education, lower income, and higher poverty levels. Container mosquito abundance has been shown to be higher in areas of low income levels [16] due to the different types of container habitats found in those areas. Socio-economic variables may have also contributed to the effectiveness of the educational program in the study sites. The number of high school and college graduates can contribute to literacy and interpretation of education materials. Winch *et al.* [1] noticed that community participation was more effective in rural and peri-urban areas, when compared to urban areas as a result of well defined social and cultural communities. Both study areas are defined as urban (over 1,000 persons per square mile [2.6 square kilometer]), under the U. S. Census Bureau's classification system. In future years, we hope to learn more about the communities, and have a more active approach to educating these communities using community peer educators.

Many educational efforts do not always have an immediate effect. Large scale source reduction efforts might not have a noticeable immediate decrease in the mosquito population when compared to insecticide treatment [1]. However, community participation can be an essential tool for developing long term, low-cost, sustainable programs [2]. Although we utilized the community in the development of brochures through surveys and focus groups, we used passive forms of education to disseminate our message. Our results suggest this method of education is too passive to motivate the public to reduce backyard mosquito habitats. Therefore, our future goals are to develop and evaluate more active community-based education programs using community peer educators.

References

1. Winch, P.; Kendall, C.; Gubler, D. Effectiveness of community participation in vector-borne disease control. *Health Policy Plann.* **1992**, *7*, 342-351.
2. Gubler, D.J.; Clark, G.G. Community involvement in the control of *Aedes aegypti*. *Acta Trop.* **1996**, *61*, 169-179.
3. Richards, S.L.; Ghosh, S.K.; Zeichner, B.C.; Apperson, C.S. Impact of source reduction on the spatial distribution of larvae and pupae of *Aedes albopictus* (Diptera: Culicidae) in suburban neighborhoods of a piedmont community in North Carolina. *J. Med. Entomol.* **2008**, *45*, 617-828.
4. Swaddiwudhipong, W.; Chaovakiratipong, C.; Nguntra, P.; Koonchote, S.; Khumklam, P.; Lerdlukanavong, P. Effect of health education on community participation in control of dengue hemorrhagic fever in an urban area of Thailand. *Southeast Asian J. Trop. Med. Public Health* **1992**, *23*, 200-206.
5. Kramer, L.D.; Styer, L.M.; Ebel, G.D. A global perspective on the epidemiology of West Nile virus. *Annu. Rev. Entomol.* **2008**, *53*, 61-81.
6. Hamer, G.L.; Kitron, U.D.; Brawn, J.D.; Loss, S.R.; Ruiz, M.O.; Goldberg, T.L.; Walker, E.D. *Culex pipiens* (Diptera: Culicidae): A bridge vector of West Nile virus to humans. *J. Med. Entomol.* **2008**, *45*, 125-128.
7. Barr, A.R. Review of the *Culex fatigans* problem in North America with special reference to urbanization. *WHO Vector Control.* **1965**, *125*, 29-32.

8. Miyagi, I. Feeding habits of some Japanese mosquitoes on cold-blooded animals in the laboratory. *Trop. Med. Nagasaki*. **1972**, *14*, 203-217.
9. Sardelis, M.R.; Dohm, D.J.; Pagac, B.; Andre, R.G.; Turell, M.J. Experimental transmission of Eastern Equine Encephalitis virus by *Ochlerotatus j. japonicus* (Diptera: Culicidae). *J. Med. Entomol.* **2002**, *39*, 480-484.
10. Nawrocki, S.J.; Hawley, W.A. Estimation of the northern limits of distribution of *Aedes albopictus* in North America. *J. Am. Mosquito Contr.* **1987**, *3*, 314-317.
11. Scott, T.W.; Lorenz, L.H.; Weaver, S.C. Susceptibility of *Aedes albopictus* to infection with eastern equine encephalomyelitis virus. *J. Am. Mosquito Contr.* **1990**, *6*, 274-278.
12. Unlu, I.; Farajollahi, A.; Healy, S.P.; Crepeau, T.; Bartlett-Healy, K.; Williges, E.; Strickman, D.; Clark, G.G.; Gaugler, R.; Fonseca, D.M. Area-wide management of *Aedes albopictus*: Choice of study sites based on geospatial characteristics, socioeconomic factors, and mosquito populations. *Pest Manag. Sci.* **2011**, (in press).
13. Schreiber, E.T.; Morris, C.D. Evaluation of public information packets for mosquito source reduction in two Florida cities. *J. Am. Mosquito Contr.* **1995**, *11*, 186-190.
14. Schreiber, E.T.; Cuda, J.P. Evaluation of public information packets for source reduction in three socioeconomic areas of Tampa, Florida. *J. Am. Mosquito Contr.* **1994**, *10*, 154-162.
15. Rios, J.; Hacker, C.S.; Hailey, C.A.; Parsons, R.E. Demographic and spatial analysis of West Nile virus and St. Louis encephalitis in Houston, Texas. *J. Am. Mosquito Contr.* **2006**, *22*, 254-263.
16. Chambers, D.M.; Young, L.F.; Hill, H.S. Backyard mosquito larval habitat availability and use as influenced by census tract determined resident income levels. *J. Am. Mosquito Contr.* **1986**, *2*, 539-544.