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Use of the CDC Autocidal Gravid Ovitrap to Control and Prevent Outbreaks of *Aedes aegypti* (Diptera: Culicidae)

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Abstract

Populations of *Aedes aegypti* (L.) can be managed through reductions in adult mosquito survival, number of offspring produced, or both. Direct adult mortality can be caused by the use of space sprays or residual insecticides to mosquito resting sites, and with a variety of residual insecticide-impregnated surfaces that are being tested, such as curtains, covers for water-storage vessels, bednets, and ovitraps. The fertility of *Ae. aegypti* populations can be reduced by the use of autocidal oviposition cups that prevent the development of mosquitoes inside the trap by mechanical means or larvicides, as well as by releasing sterile, transgenic, and para-transgenic mosquitoes. Survival and fertility can be simultaneously reduced by capturing gravid female *Ae. aegypti* with sticky gravid traps. We tested the effectiveness of the novel Centers for Disease Control and Prevention autocidal gravid ovitrap (CDC-AGO trap) to control natural populations of *Ae. aegypti* under field conditions in two isolated urban areas (reference vs. intervention areas) in southern Puerto Rico for 1 yr. There were significant reductions in the captures of female *Ae. aegypti* (53–70%) in the intervention area. The presence of three to four AGO control traps per home in 81% of the houses prevented outbreaks of *Ae. aegypti*, which would be expected after rains. Mosquito captures in BG-Sentinel and AGO traps were significantly and positively correlated, showing that AGO traps are useful and inexpensive mosquito surveillance devices. The use of AGO traps to manage *Ae. aegypti* populations is compatible with other control means such as source reduction, larviciding, adulticiding, sterile insect techniques, induced cytoplasmic incompatibility, and dominant lethal gene systems.

Keywords

Aedes aegypti; vector control; mosquito trap; dengue; outbreak

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Aedes aegypti (L.) control is mainly directed against immature stages (education, source reduction, and larviciding) to reduce the production of new adult mosquitoes, with some efforts devoted to controlling adult mosquitoes using spatial sprays of adulticides during dengue outbreaks (Pilger et al. 2010). In addition to the problem of insecticide resistance in *Ae. aegypti* (Ranson et al. 2010), there are several drawbacks that preclude achieving effective vector control: 1) Coverage of control measures is limited because only a fraction

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of the human dwellings is ever treated (residents are absent or deny access to control personnel), which means that only a smaller fraction of the *Ae. aegypti* population can be reduced, leading to recolonization of the area; 2) The effects of larvicides and adulticides are short-lived (days), thus requiring reapplication at a frequency that is impractical for most programs because of a shortage of personnel and resources; and 3) There has been a lack of entomological indicators that can be used to independently evaluate the impact of the control measures directed at the immature stages, such as measuring the resulting number of adult female *Ae. aegypti* (Barrera et al. 2008). Residual insecticides that target adult *Ae. aegypti* were used during the eradication era, but they are no longer the main approach of dengue vector control programs (World Health Organization [WHO] 2009). Therefore, newer tools are needed for the surveillance of adult *Ae. aegypti* and for controlling this vector using integrated means.

Ae. aegypti populations can be managed by increasing adult mortality or by reducing population fertility. An example of the latter approach is the release of genetically altered (McDonald et al. 1977), transgenic (Harris et al. 2011), or para-transgenic (O'Connor et al. 2012) males to mate with wild females that eliminate or interfere with offspring production. The other method of reducing fertility is by means of autocidal ovitraps. These devices collect eggs of *Ae. aegypti* and prevent hatching larvae from ever completing their development and emergence as adults, through either mechanical means (Chan et al. 1977, Cheng et al. 1982) or chemical control (Regis et al. 2008). Direct adult mortality can be caused by a number of insecticide-impregnated tools that are currently undergoing field testing, such as curtains and covers for water-storage vessels (Kroeger et al. 2006), bednets (Lenhart et al. 2008), and “lethal” ovitraps (Zeichner and Perich 1999, Perich et al. 2003, Sithiprasasna et al. 2003, Kittayapong et al. 2006, Williams et al. 2007b, Ritchie et al. 2008, Rapley et al. 2009). Another class of novel devices that kills female adults of *Ae. aegypti* are the various models of sticky gravid traps that are being used for surveillance purposes (Ordoñez-Gonzalez et al. 2001, Ritchie et al. 2004, Fávaro et al. 2006, Facchinelli et al. 2007, Gomes et al. 2007, Chadee and Ritchie 2010, de Santos et al. 2012, Lee et al. 2013, Wu et al. 2013, current study).

The objectives of this study were to test the effectiveness of a novel sticky trap: the Centers for Disease Control and Prevention autocidal gravid ovitrap (CDC-AGO trap; patent pending; Mackay et al. 2013) for controlling natural populations of *Ae. aegypti* in two urban areas in southern Puerto Rico and to compare the AGO traps with BG-Sentinel traps to determine whether they are useful vector surveillance devices. AGO traps capture gravid female *Ae. aegypti* causing direct adult mosquito mortality, lowering the biting rate, and reducing population fertility. Because gravid females have fed on blood at least once to produce eggs and could have acquired dengue viruses from an infected person during any of the previous bloodmeals, controlling gravid females is also important to reduce dengue virus transmission. To be a practical tool for managing dengue vectors, a trap must be specific, effective, inexpensive, simple to construct and operate, and it should not require frequent maintenance. Traps that do not use toxic pesticides are more likely to be acceptable to homeowners concerned with potential health and environmental hazards of using these chemicals in and around their home and will not contribute to the development of resistance to insecticides in the vector population. The AGO trap was designed to: 1) improve the potential of the basic ovitrap to compete with other container habitats by increasing the intensity of visual and olfactory cues emitted by an individual trap, and 2) incorporate simple low-cost mechanisms for eliminating gravid *Ae. aegypti* and their progeny that do not rely on insecticides, and that can remain efficacious for an extended period of time without servicing (>2 mo; Mackay et al. 2013).

Materials and Methods

Study Areas

This study was conducted in two relatively isolated neighborhoods located 20 km apart in southern Puerto Rico: La Margarita (17° 58′18″ N, 66° 18′10″ W; 3 m elevation; 327 buildings; 18 ha) and Villodas (17° 58′13″ N, 66° 10′48″ W; 20 m elevation; 241 buildings; 11 ha). La Margarita and Villodas were 200 and 500 m from other urbanized areas, respectively. Both communities have reliable access to sanitary services such as piped water, domestic garbage pickup, and sewerage. Average temperature and accumulated rainfall (26 October 2011 to 23 October 2012) were 27.0°C and 570 mm in La Margarita and 26.6°C and 727 mm in Villodas, respectively. There was a cooler and drier season from December to March and a warmer and wetter season the rest of the year in both study areas (Fig. 1). Preliminary pupal surveys (July–August 2011) showed similar pupal density per house in La Margarita (7.7 ± 1.6; mean ± SE) and Villodas (6.6 ± 1.6; mean ± SE; CDC, unpublished). We chose La Margarita as the intervention area because it was larger than Villodas and closer to our field laboratory in downtown Salinas.

Experimental Design

The effectiveness of the AGO trap to reduce the adult population of *Ae. aegypti* was investigated by comparing temporal changes in relative mosquito population density (individuals per trap per time) between two urbanized areas—one with AGO control traps (AGO; three or four traps per house; intervention area, La Margarita) and another one without AGO traps (reference area, Villodas). The number of control traps used per home was investigated in a previous study where we found that the number of mosquitoes captured per trap per home decreased when using three or four traps per home (CDC, unpublished). The study was conducted from October 2011 to October 2012 and consisted of the following activities: 1) A preintervention or baseline study (9 wk from October to December 2011) to compare *Ae. aegypti* densities between areas and to a allow comparisons within areas before and after interventions; 2) source reduction, larviciding, and egg removal of both study areas, and installation of AGO traps in the intervention community (December 2011); and 3) postintervention follow-up assessment of *Ae. aegypti* density in both study areas (weekly from December 2011 to October 2012).

Traps: CDC Autocidal Gravid Ovitrap

The AGO trap (Mackay et al. 2013; Fig. 2) consists of nine basic components: 1) 3/4″ black polypropylene netting (Industrial Netting, Minneapolis, MN) covering the entrance of the trap to exclude the entry of larger debris or organisms; 2) 3.8-liter black polyethylene cylinder that serves as the trap entrance (12.8 cm in diameter) and capture chamber; 3) sticky surface covering the interior of the capture chamber that is made of a black styrene cylinder (16 cm in diameter); the inner surface is coated with 155 g/m^2 of a nonsetting polybutylene adhesive (Ritchie et al. 2004; 32UVR, Atlantic Paste & Glue Co. Inc., Brooklyn, NY); 4) screen barrier at the bottom of the capture chamber to prevent adult mosquitoes from moving between the capture chamber and the infusion reservoir. It also prevents any mosquito emerging from the infusion to escape from the trap (occasionally, eggs from captured females may be washed by rain into the infusion reservoir and develop into adult mosquitoes); 5) black pail lid; 6) black polyethylene pail (19 liters of volume); 7) Drainage holes to allow excess infusion to drain from the trap (maximum infusion capacity 10 liters); 8) 10 liters of water, and 9) 30 g hay packet. Traps were serviced every 2 mo to replace the water lost to evaporation, hay packet, and sticky surface. The cost of materials was calculated at US$12.5 per trap without labor, and we hope to reduce its cost once the trap can be mass-produced.

Three AGO traps were placed outdoors in the garden, patio, or porch of houses in the intervention community for the first 2 mo of the postintervention study (812 traps; December 2011–February 2012). Because we noted that some lizards were being caught on the sticky surface of the traps, we increased the number of AGO traps to four per house (1,004—1,050 traps; March–October 2012) to compensate for possible loss of attraction as a result of the odor of decaying lizards. The average percentage of houses with control traps in La Margarita was 81% during the study. We did not monitor mosquito captures in the AGO traps, which were left undisturbed for periods of 2 mo at a time before servicing.

In addition to the traps that we used for control purposes (AGO), we deployed 44 (2.4 traps/ha) and 27 (2.5 traps/ha) sentinel AGO (SAGO) traps in the intervention and reference areas, respectively, to monitor the weekly abundance of female *Ae. aegypti*. Sentinel AGO traps were checked every week, and the trapped specimens were removed from the sticky trap surface using forceps, placed on white paper napkins, sexed, visually identified to species, and enumerated directly in the field. Sentinel AGO traps were also serviced every 2 mo to replace water, hay pack, and sticky surfaces. Results of SAGO trap collections are presented as number of female *Ae. aegypti* per trap per week (7-d captures). Few males were captured in AGO traps.

BG-Sentinel Traps

Modified BG-Sentinel traps without lure (Biogents, Regensburg, Germany) were also used to monitor the density of adult *Ae. aegypti* and to compare mosquito captures with SAGO traps. We did not use the BG trap's chemical lure because we have observed that this trap efficiently captures *Ae. aegypti* without it and to reduce the cost of operating the traps. The modified trap had a black outer cover instead of the original white one. Black BG traps captured 38% more *Ae. aegypti*, 79% more *Aedes mediovittatus* (Coquillett), and 15% more *Culex quinquefasciatus* Say than the original model in studies conducted in Puerto Rico (CDC, unpublished). We used 44 (2.4 traps/ha) and 28 (2.5 traps/ha) BG-sentinel traps in the intervention and reference areas, respectively, to monitor the weekly abundance of *Ae. aegypti*. Black BG traps were operated for three consecutive days every week. Collecting bags were changed every day and batteries changed after the second day of operation.

Collected specimens were stored at −80°C. We used stereoscopes to identify and enumerate the specimens collected. Results of BG trap collections were presented and analyzed as numbers of adult male or female *Ae. aegypti* collected per BG trap for 3 d of collections per week.

We used a map of buildings and streets (Property Tax Office of Puerto Rico) within a Geographical Information System (GIS; ArcView 10, Esri, Redlands, CA) of La Margarita and Villodas to plan for the uniform deployment of fixed-position BG-Sentinel and SAGO traps across each study area. Traps were spaced at distances >30 m because it has been shown that *Ae. aegypti* adults cluster within that distance (Getis et al. 2003). Resulting average intertrap distances were 55 m for BG traps, 44 m for SAGO traps, and 25 m between any traps in the La Margarita, and 59 m for BG traps, 47 m for SAGO traps, and 29 m between any traps in Villodas.

Source Reduction, Larviciding, and Oviciding

Before installing the AGO traps in La Margarita (intervention area), we conducted source reduction, larviciding, and oviciding, in both study areas to reduce the availability of containers with water and reduce the population of *Ae. aegypti* to lower levels. Source reduction consisted of the removal of all discarded containers that the owners authorized us to remove. We used three formulations of the larvicide Natular (spinosad) in granular (G) and tablet (T30 and XRT) formulations (Clarke, Roselle, IL). The larvicides were applied at the dosages recommended by the maker and approved by the Environmental Protection Agency (EPA) to containers that could not be removed and whose water was not for animal or human consumption. Granular formulation of Natular (G) was applied at 0.3 g/liter. Tablet formulation T30 was used in large containers such as boats and broken appliances (e.g., washer machines), whereas Tablet formulation XRT was applied to broken or open septic tanks. The inner walls of containers that could not be removed were also brushed and rinsed to remove *Ae. aegypti* eggs.

Statistical Analyses

To establish if adult mosquito abundance was similar between the two study areas before intervening with control measures (October–December 2011), we tested the null hypothesis that the number of female or male *Ae. aegypti* per BG or SAGO trap per week was the same in both study areas. We used a generalized linear mixed model to test for the effects of study area, accumulated rainfall during the third and second weeks before sampling, and average air temperature during the 3 wk before sampling. The distribution probability function of the dependent variable was the negative binomial with log link. The covariance structure for the repeated estimation of mosquito density per trap per week was a first-order autoregressive function. Trap ID was used as a random factor to account for individual trap bias using a covariance component identity matrix.

Similar analyses were performed to test the hypothesis that the number of female or male *Ae. aegypti* per BG or SAGO trap per week was the same in the two study areas after the intervention (source reduction, larviciding, and oviciding in both areas in December 2011; deployment of AGO control traps in La Margarita, December 2011–October 2012). The relationship between average captures of female *Ae. aegypti* per trap per day for each week in BG and SAGO traps was explored using a reduced major axis regression analysis (regression type II). Statistical analyses were conducted in IBM SPSS Statistics 12 (IBM Corporation, Armonk, NY). A similar regression analysis was also used to compare the weekly reduction in female *Ae. aegypti* in the intervention area with the reference area.

Results

Preintervention

The average numbers of female *Ae. aegypti* per BG (F = 2.04; P > 0.05) or SAGO (F = 0.04; P > 0.05) traps per week were not significantly different between study areas before the initiation of control measures, from October to December of 2011 (Table 1; Fig. 3). Rainfall was a significant covariate (F = 47.2; P < 0.001) that was positively associated with the average number of mosquitoes per trap. In general, BG traps captured more mosquitoes per unit time than SAGO traps if we consider that the former were operated for 3 d/wk and the latter for an entire week.

BG traps also captured more male *Ae. aegypti* than SAGO traps (Table 1). More males were captured per BG trap in La Margarita (F = 4.71; P < 0.05; 2.2 males/trap/wk; 1.6–3.0, model-estimated means; 95% CI) than in Villodas (1.3; 0.9–1.9) before the intervention (Table 1). As with female mosquitoes, rainfall was significantly and positively associated with the number of males in BG traps (F = 16.6; P < 0.001). Temperature was not a significant covariate in the preintervention study and was taken out of the final models.

Postintervention

The average numbers of female *Ae. aegypti* per BG or SAGO traps per week were significantly different between areas with and without AGO traps (Tables 1 and 2; Fig. 3). Overall captures rates in BG traps were 2.15 times (1.64–2.82; 95% CI) smaller in the intervention area than in the reference area, which is equivalent to a 53% reduction in female *Ae. aegypti* after allowing for rainfall and temperature effects (Table 2). Model-estimated means were 3.0 (2.4–3.7) females per BG trap per week in the reference area and 1.4 (1.2–1.6) females per BG trap in the intervention area. There were no significant differences in the number of males captured per BG trap in the study areas with and without control traps (F = 0.24; P> 0.05). Model-estimated means were 1.4 (1.0–2.1) males per trap in the reference area and 1.2 (0.0–1.7) in the intervention area.

The overall density of female *Ae. aegypti* per SAGO trap per week in the intervention area was 3.4 (2.6–4.4) times smaller than in the reference area, which is equivalent to a 70% reduction in the number of mosquitoes after allowing for rainfall and temperature effects. Model-estimated means for SAGO traps were 3.3 (2.7–4.0) females per trap per week in the reference area and 1.0 (0.8–1.2) in the intervention area (Table 2).

Rainfall (F = 67.7; P < 0.001) and temperature (F = 79.1; P < 0.001) were significant covariables that were positively associated with mosquito density in both types of traps through time (Table 2). Sharp increases in mosquito captures were observed following rainfall events using both traps, particularly in the area without control traps (Fig. 3).

Furthermore, differences in mosquito densities between study areas were largest during the first (April and May) and second rainy seasons (August and September; Fig. 3).

The average numbers of female *Ae. aegypti* per BG or SAGO trap showed a highly heterogeneous spatial pattern before the intervention in both communities and were more homogeneous in the area with control traps after the intervention (Figs. 4 and 5). A postintervention reduction in the abundance of female *Ae. aegypti* in La Margarita is evident in the maps, where there are more areas with low capture rates and fewer spots with high capture rates in both the SAGO and BG traps after the AGO traps were deployed (Figs. 4 and 5).

Assuming that the reductions of female *Ae. aegypti* in the intervention area were mainly a result of the presence of control traps, we plotted the deficit of female *Ae. aegypti* in the intervention area (difference in mosquito density between the reference and intervention areas) against the density in the reference area (without control traps). The data analyzed here were from weeks 20 through 52, some prudent time after applying immature control activities (weeks 9–11) in an effort to isolate the action of the control traps. There was a highly significant positive linear relationship between the deficits of female *Ae. aegypti* and the density of this species in the reference area in both types of traps (Fig. 6). Capture rates of BG and SAGO traps were constant and similar throughout the observed range of mosquito densities in the reference study area, without any evidence of saturation or leveling off (Fig. 6).

Comparison of BG and SAGO Trap Captures

The relationship between the average numbers of female *Ae. aegypti* captured in BG and SAGO traps per day for all the weeks of the study (n = 52; Fig. 7A) was significant for samples collected in the intervention (Log10 females per AGO trap per day = −0.586 [−0.659–−0.513; 95% CI] + 0.709 [0.459–0.959] × Log10 females per BG trap per day; R^2 = 0.482) and reference areas (Log10 females per AGO trap per day = −0.369 [−0.424–−0.313; 95% CI] + 0.770 [0.664–0.876] × log10 females per BG trap per day; R^2 = 0.743). In the reference area, the relationship was less variable and the model had a better fit to the data collected.

Significant and positive relationships were evident between percentages of SAGO and BG traps capturing at least one female *Ae. aegypti* (Fig. 7B) in the intervention (Percentage of positive AGO traps per week = 0.170 [−0.032–0.372; 95% CI] + 0.628 [0.352–0.904] × Percentage of positive BG traps per week; R^2 = 0.369) and reference areas (Percentage of positive AGO traps per week = 0.320 [0.208–0.431; 95% CI] + 0.619 [0.461–0.777] × Percentage of positive BG traps per week; R^2 = 0.552). Again, the modeled relationship for trap positivity in the reference area was better than the one for the intervention area. The slopes of the regressions for mosquito density and trap positivity between BG and SAGO traps were similar in both localities, but there were relatively smaller captures in SAGO traps in relation to BG traps in the study area with control traps (Fig. 7).

Discussion

Ae. aegypti Control

This investigation used CDC-AGO to control *Ae. aegypti* in a relatively isolated urban area (327 buildings) in southern Puerto Rico that was compared with another urban area (241 buildings) that had similar mosquito population dynamics and environmental conditions (Figs. 1 and 3). Postintervention reductions in the number of female *Ae. aegypti* captured in BG and SAGO traps attributable to the presence of the AGOs were 53 and 70%, respectively. More notably, the presence of the control traps prevented outbreaks of *Ae. aegypti* that were observed in the reference community after increased rainfall (Fig. 3). We believe that outbreak suppression was caused by significant reductions in the number of eggs that accumulated in container habitats (i.e., "egg bank"), which usually hatch after rains, producing bursts of new adult mosquitoes (Keirans and Fay 1970). In a previous study, we found a significant positive relationship between the number of eggs in conventional ovitraps (Reiter et al. 1991) and the number of female *Ae. aegypti* captured in paired SAGO traps in San Juan city, Puerto Rico (Mackay et al. 2013). It can also be observed that the number of female mosquitoes in the area with control traps tended to increase following rains but at a lower rate than in the reference area (Fig. 3). The results of the statistical analyses also showed significant positive effects of rainfall and temperature on the number of male and female *Ae. aegypti* (Table 2), as it has been previously observed in urban Puerto Rico (Barrera et al. 2011). Thus, AGO traps seem to be effective tools to suppress outbreaks of *Ae. aegypti* in the study areas.

We explored the relationship between reductions in the density of female *Ae. aegypti* in the intervention area in relation to its density in the reference area to better understand how the sticky traps operated. The results showed that capture rates in both sentinel BG and SAGO traps were similar and constant throughout the range of *Ae. aegypti* densities observed in the study areas, without showing evidence of saturation (Fig. 6). In general, traps captured more mosquitoes at larger densities and fewer mosquitoes at smaller densities, so these traps showed some capacity to regulate the population of *Ae. aegypti*. The degree at which AGO traps were capable of reducing the population of *Ae. aegypti* was indicated by the slope of the linear models (0.821 in SAGO and 0.839 in BG traps), for which theoretical maximum value is one, meaning a total reduction of the population. If the regression lines are forced to go through the origin, the slopes changed (0.682 in SAGO and 0.609 in BG traps) toward values that are more similar to the estimated net reductions caused on the *Ae. aegypti* population by the control traps, which was around 60%. These observations suggest that a greater effect could be achieved by increasing the number of traps or by increasing the capture efficiency of individual traps.

The use of sticky traps to manage *Ae. aegypti* populations is compatible with other means of controlling *Ae. aegypti* in the immature and adult stages such as source reduction, larviciding, and adulticiding (aerosol and residual spraying of insecticides). Because AGO traps do not efficiently capture male *Ae. aegypti* (Table 1), these traps could also be used concurrently with control techniques that rely on male mosquito control delivery systems, such as the sterile insect techniques, *Wolbachia*-induced cytoplasmic incompatibility, and dominant lethal genes. AGO traps can also be a useful nonchemical means of controlling *Ae. aegypti* in areas showing resistance to insecticides (Ranson et al. 2010).

Some consideration needs to be made regarding the environmental conditions under which this study was conducted. The study areas had adequate public services, such as piped water supply, domestic garbage pickup, and sewerage, thus resembling similar environmental conditions that are prevalent in large cities in Puerto Rico and in the continental United States. The effect of the AGO traps should be investigated in urban areas with abundant permanent aquatic habitats that produce large numbers of *Ae. aegypti*, such as some water-storage vessels. Although the efficiency of the AGO to capture female *Ae. aegypti* appeared to be constant, this study did not cover all ranges in *Ae. aegypti* densities. It is likely that some complementary control measures such as source reduction or larviciding would enhance the efficacy of the traps, as suggested by Chan (1973) for autocidal ovitraps. Next steps include scaling up to test whether AGO traps can significantly prevent or control dengue outbreaks. The fact that AGO traps suppressed *Ae. aegypti* outbreaks in this study is encouraging.

Comparing BG and AGO Traps

BG traps have been shown to be more effective at capturing adult *Ae. aegypti* than other mosquito surveillance devices (Maciel-de-Freitas et al. 2006, Williams et al. 2006). These traps are portable and can be deployed in sufficient numbers to obtain reliable estimates of the relative population density of *Ae. aegypti* (Williams et al. 2007a, Ritchie et al. 2013). The main constraint in using BG traps in *Ae. aegypti* control programs is their cost and dependence on electricity, which is needed to operate the fan that draws approaching adult mosquitoes into the collection bag. For these reasons, it is important to develop simpler less expensive traps to monitor populations of adult *Ae. aegypti*.

The results of the current study showed a highly significant, positive linear relationship between numbers of female *Ae. aegypti* in BG and SAGO traps (Fig. 7). This result demonstrates that AGO traps can also be used as surveillance tools to monitor the adult population of *Ae. aegypti* despite the fact that AGO traps mainly capture gravid females. In addition, AGO traps can be deployed in relatively small numbers to obtain reliable estimations of the relative population density of gravid female *Ae. aegypti.* AGO traps are also relatively inexpensive and do not require frequent servicing, which make them affordable to vector control programs (Mackay et al. 2013).

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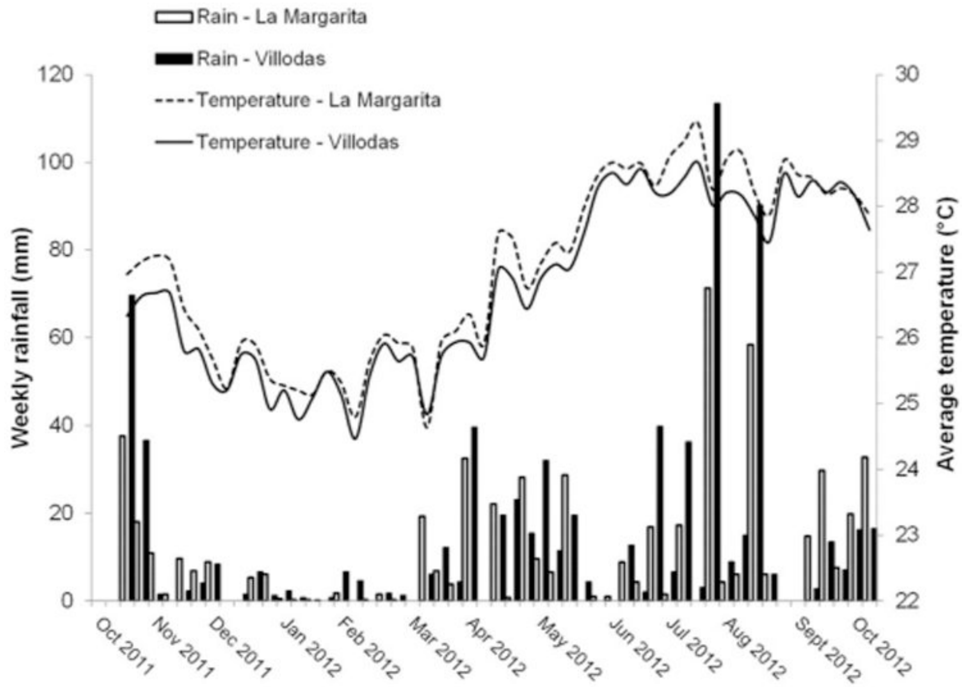

Fig. 1.

Weekly average temperature (°C) and accumulated rainfall (mm) from October 2011 to October 2012 in Villodas and La Margarita communities in southern Puerto Rico.

Fig. 2.

Description of the CDC-AGO (patent pending): (A) Black polypropylene netting to exclude the entry of debris, (B) polyethylene cylinder that serves as the trap entrance and capture chamber, (C) sticky surface made of a black styrene cylinder coated with a nonsetting adhesive, (D) screen barrier to prevent adult mosquitoes from reaching the infusion reservoir, (E) black pail lid, (F) black polyethylene pail, (G) drainage holes, (H) water, and (I) hay packet.

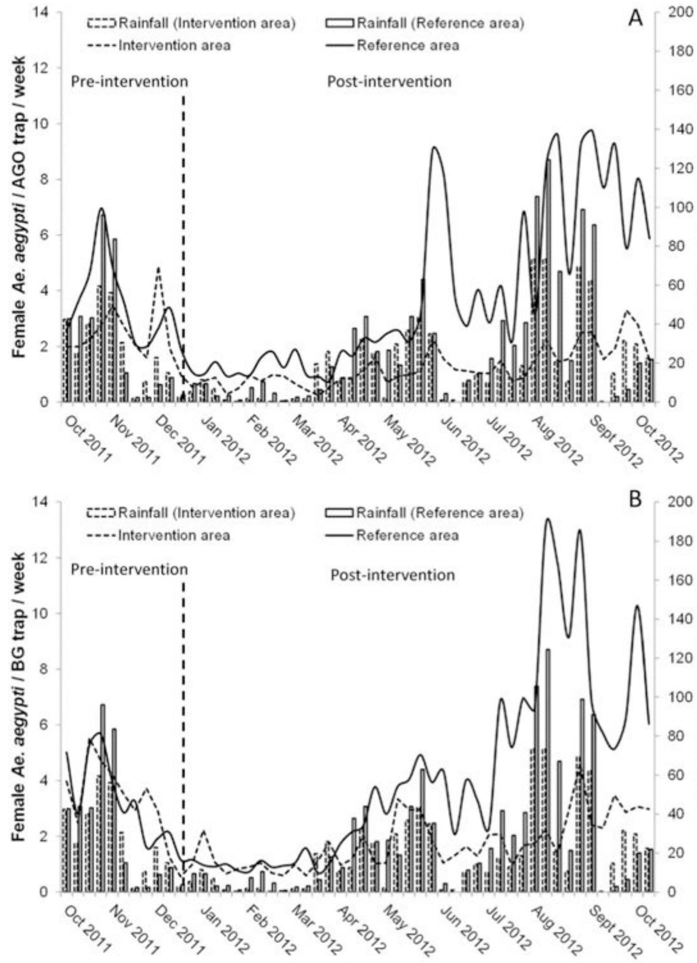

Fig. 3.

(A, B) Weekly variation in the numbers of female *Ae. aegypti* captured in BG-Sentinel (sum of 3-d captures per week) and SAGO (7-d captures) traps, and accumulated rainfall (second and third weeks before sampling) in the reference (Villodas) and intervention (La Margarita) areas. Mosquitoes were monitored in both areas before applying control measures from October to December 2011 and afterwards until October 2012, following the intervention. Rainfall data are plotted with a forward lag time of 2 wk to facilitate visual association with the numbers of mosquitoes.

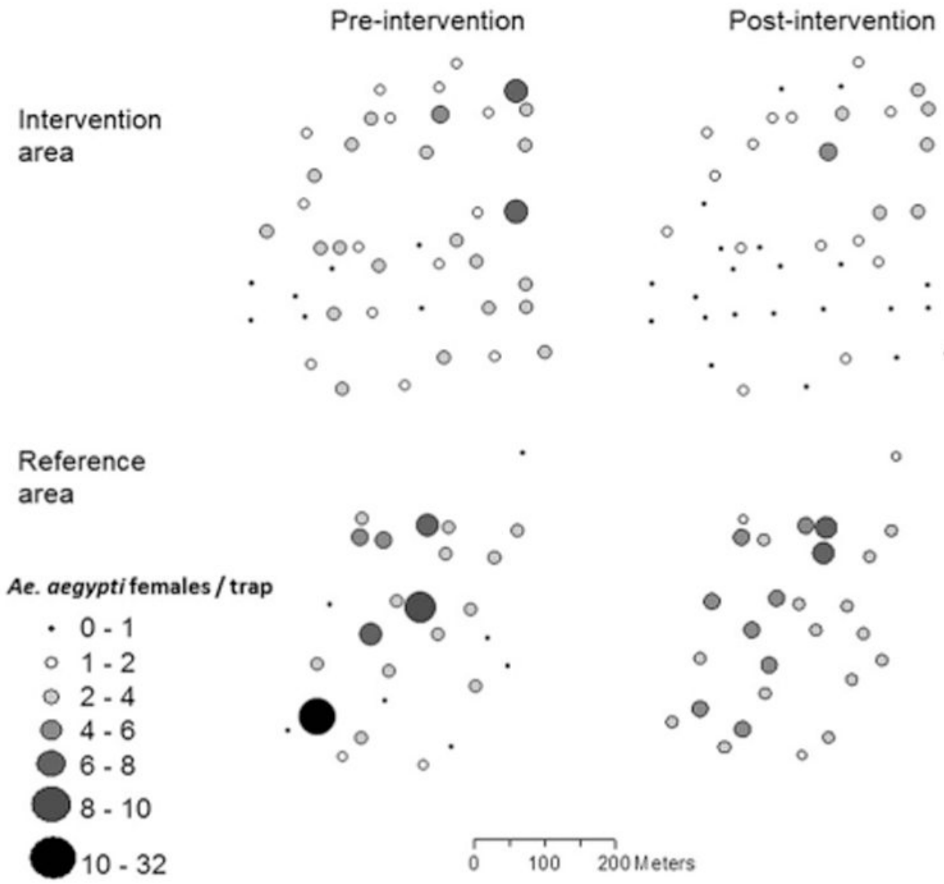

Fig. 4.

Maps showing the location of SAGO traps and changes in overall weekly averages of female *Ae. aegypti* per trap before (October–December of 2011) and after the intervention (December 2011–October 2012) in the two study areas.

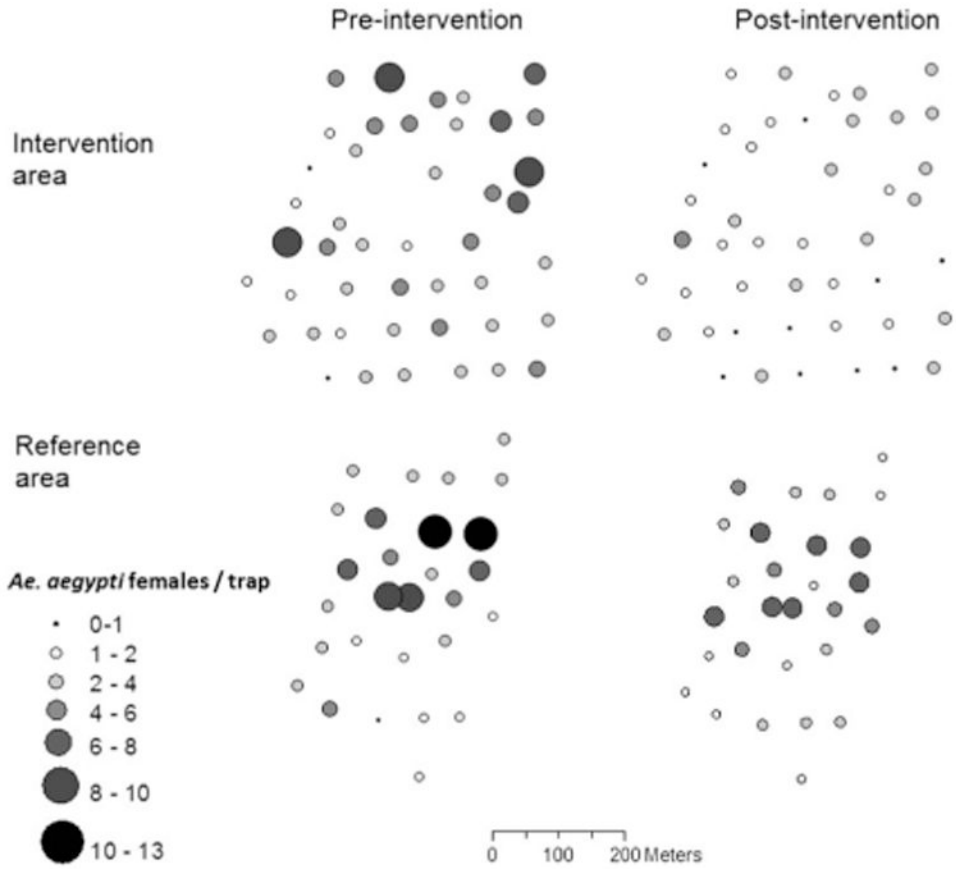

Fig. 5.

Maps showing the location of BG-Sentinel traps and changes in overall weekly averages of female *Ae. aegypti* per trap before (October–December of 2011) and after the intervention (December 2011–October 2012) in the two study areas.

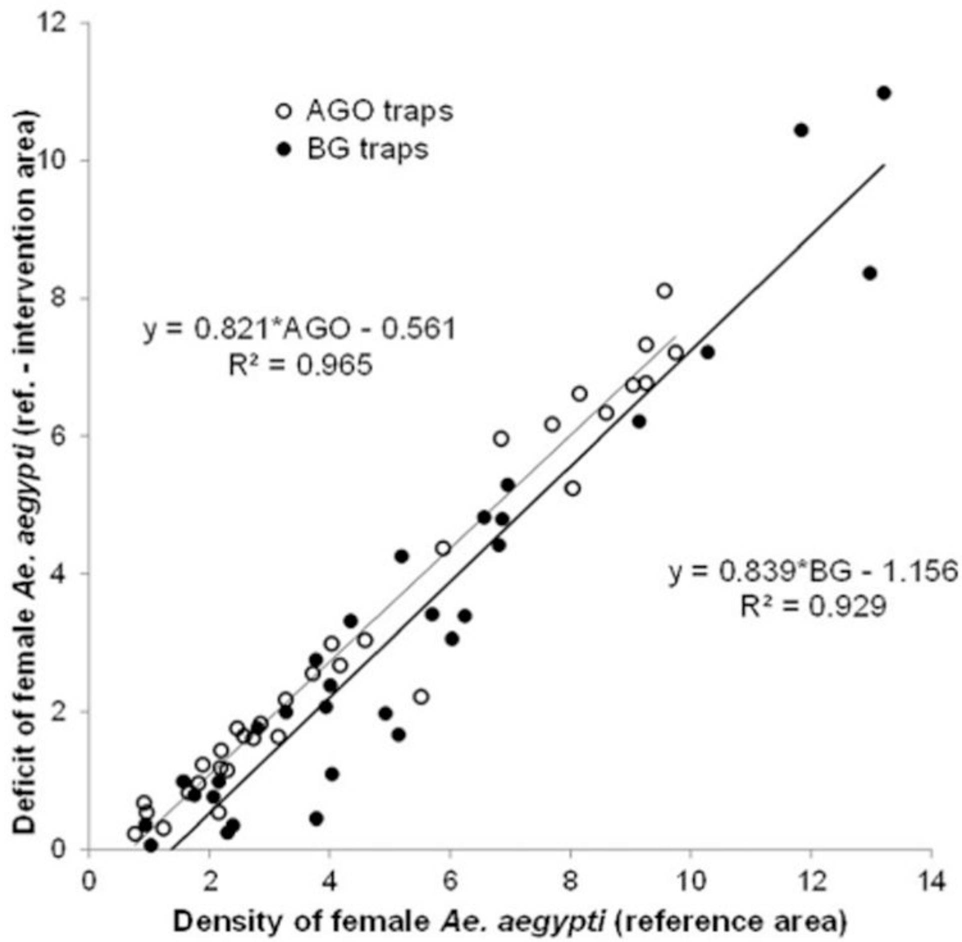

Fig. 6.

Deficit of female *Ae. aegypti* in the intervention area (difference in mosquito density between the reference and intervention areas per week) against the density in the reference area (without control traps), from weeks 20 through 52 to show the reduction in numbers caused by the control traps.

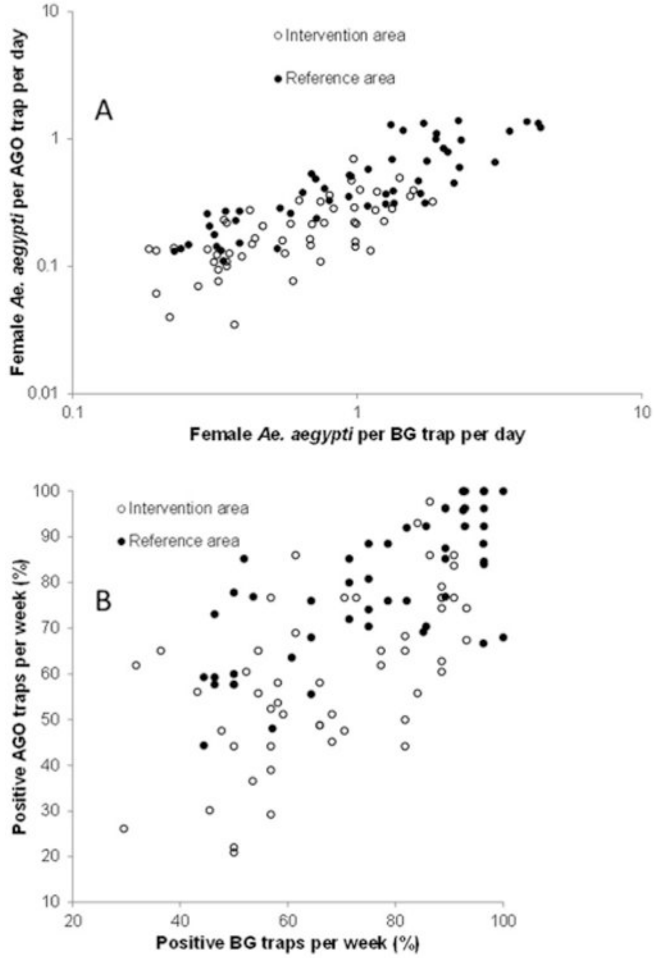

Fig. 7.

(A) Plot of average numbers of female *Ae. aegypti* captured in SAGO and BG-Sentinel traps per day for all the weeks of the study. (B) Comparison of the percentages SAGO and BG-Sentinel traps that were positive for female *Ae. aegypti* per week during the study.

Table 1

Average (±95% CI, sample size in parentheses) female and male *Ae. aegypti* captured per BG trap (3-d capture per week) or per SAGO trap (7-d capture per week) in the reference and intervention areas before and after deploying the AGO control traps

Sentinel trap	Period of study	Reference area (Villodas)	Intervention area (La Margarita)
BG traps	Preintervention		
	Females	3.60 ± 0.24 (251)	3.78 ± 0.18 (396)
	Males	2.31 ± 0.26	3.22 ± 0.22
	Postintervention		
	Females	4.06 ± 0.16 (1,196)	1.74 ± 0.33 (1, 889)
	Males	2.62 ± 0.15	2.18 ± 0.10
SAGO traps	Preintervention		
	Females	3.69 ± 0.51 (231)	2.65 ± 0.13 (387)
	Males	0.21 ± 0.18	0.13 ± 0.02
	Postintervention		
	Females	3.83 ± 0.14 (1,123)	1.25 ± 0.05 (1, 828)
	Males	0.10 ± 0.02	0.06 ± 0.01

Table 2

Comparison of the average number of female *Ae. aegypti* in BG (3-d capture per week) or sentinel AGO traps (7-d capture per week) between the reference (Villodas) and intervention (La Margarita) study areas after the deployment of AGO traps

Sentinel trap	Model term	Coefficient	SE	*t*	*P* value	Exp (coefficient)	95% CI lower for exp (coefficient)	95% CI upper for exp (coefficient)
BG traps	Intercept	−7.432	0.611	−12.174	<0.001	0.001	0.000	0.002
	No control traps	0.765	0.138	5.542	<0.001	2.148	1.639	2.816
	With control traps	0[a]	–	–	–	–	–	–
	Rainfall	0.009	0.001	10.810	<0.001	1.009	1.008	1.011
	Temp	0.281	0.022	12.564	<0.001	1.325	1.268	1.384
AGO traps	Intercept	−7.263	0.598	−12.268	<0.001	0.001	0.000	0.002
	No control traps	1.212	0.134	9.038	<0.001	3.359	2.583	4.370
	With control traps	0[a]	–	–	–	–	–	–
	Rainfall	0.006	0.001	7.533	<0.001	1.006	1.005	1.008
	Temp	0.264	0.022	12.178	<0.001	1.302	1.248	1.359

The results shown are from generalized linear mixed-model analyses using a negative binomial model with log link function.

Variables tested on female mosquito density were the presence or absence of AGO control traps, accumulated rainfall during the third and second weeks before sampling, and average air temperature for 3 wk before sampling.

[a]This coefficient is set to zero because it is redundant.