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# FIELD COMPARISON OF NOVEL AND GOLD STANDARD TRAPS FOR COLLECTING *AEDES ALBOPICTUS* IN NORTHERN VIRGINIA

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ABSTRACT. *Aedes albopictus* is a potential West Nile virus bridge vector in Northern Virginia; however, information regarding its virus transmission dynamics is limited, as this species is not readily collected in existing traps. This study used 5 replicates of a 5 × 5 Latin square to evaluate the efficiency and effectiveness of 2 novel host-seeking mosquito traps (the BG-Sentinel™ and the Collapsible Mosquito Trap (CMT-20™) in collecting *Ae. albopictus,* relative to a carbon dioxide ($CO_2$)–baited Centers for Disease Control and Prevention (CDC) miniature light trap. When used with $CO_2$, the BG-Sentinel (with BG-Lure) collected 33 times more female *Ae. albopictus* per 24-h trapping period than did the $CO_2$-baited CDC light trap. Without $CO_2$, the BG-Sentinel (with BG-Lure) still collected over 6 times as many female *Ae. albopictus* as the $CO_2$-baited CDC trap. Both configurations of the BG-Sentinel were significantly more effective than the other traps. The BG-Sentinel was also significantly more efficient in collecting *Ae. albopictus* and collected a high proportion of this species, both with $CO_2$ and without $CO_2$. The CMT-20 (with SkinLure™) collected significantly more *Ae. albopictus* when used with $CO_2$ than without $CO_2$, but did not collect significantly more *Ae. albopictus* than the $CO_2$-baited CDC light trap. The proportion of *Ae. albopictus* collected in the CMT-20 with $CO_2$ and without $CO_2$ did not differ significantly from the proportion of *Ae. albopictus* collected in the CDC trap.

**KEY WORDS** Centers for Disease Control and Prevention miniature light trap, BG-Sentinel™, CMT-20™ (Zumba™), *Aedes albopictus*, adult mosquito surveillance

## INTRODUCTION

*Aedes albopictus* (Skuse) is a potential West Nile virus (WNV) bridge vector (Sardelis et al. 2002, Turell et al. 2005) in Northern Virginia and has become established as the primary nuisance mosquito in the area. Information regarding the abundance of this species as well as the extent of its involvement in the WNV transmission cycle is limited, as this species is not readily collected by existing traps, including Centers for Disease Control and Prevention (CDC) light traps, which are considered the industry standard for mosquito surveillance. Also, the ability to detect the virus from field-collected *Ae. albopictus* is limited by low trap collections, and field collections of this species in Northern Virginia have rarely tested positive for WNV (Fairfax County and Virginia Department of Health, unpublished data). Incorporating a more efficient trap to collect *Ae. albopictus* into the routine mosquito surveillance activities in this area would provide a more accurate estimation of the true WNV burden of this species in Northern Virginia. Furthermore, such a trap would allow mosquito control professionals to assess the efforts of homeowners and others in eliminating standing water and reducing the abundance of *Ae. albopictus.*

Two novel mosquito traps (the BG-Sentinel™ and the Collapsible Mosquito Trap [CMT-20]™—prototype of the Zumba™ mosquito trap) were evaluated in their ability to collect *Ae. albopictus*. The effectiveness (measured as the mean number of *Ae. albopictus* collected per trapping period) and the efficiency (measured as the proportion of *Ae. albopictus* collected) of these novel traps were evaluated relative to the CDC light trap.

The BG-Sentinel has been shown to work particularly well in collecting disease vectors and nuisance mosquito species from around the world. Several studies in Australia and Brazil show that the BG-Sentinel is an effective tool for collecting *Ae. aegypti* L. (Krockel et al. 2006, Maciel de Feitas et al. 2006, Rose et al. 2006, Williams et al. 2006, 2007) and *Ae. albopictus* (Ritchie et al. 2006). In American Samoa, the BG-Sentinel collected more *Ae. polynesiensis* (Marks) than did both CDC and Fay-Prince traps (Ball 2005), and in Germany, the BG-Sentinel was shown to be effective in collecting *Culex pipiens* L. (Rose et al. 2006).

In terms of collecting *Ae. albopictus*, the only documented field trials involving the BG-Sentinel have taken place in northern Italy, where this trap was compared to the CAA trap (a CDC-type trap used in Italy). There, the BG-Sentinel collected greater numbers of mosquitoes (and *Ae. albopictus*) than the CAA (Bitzhenner et al. 2005). Prior to this study, there was no published data relating to the performance of the BG-Sentinel mosquito trap in suburban areas of the United States.

In field trials in Colorado, the $CO_2$-baited CMT-20 trap performed better than the $CO_2$-baited CDC trap (Coler 2005). Similar trials were conducted in Texas, where the CMT-20 outper-

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formed the CDC trap, both in terms of the total number of species collected and the proportion of host-seeking *Aedes* spp. collected (Coler 2005). The Zumba trap (successor of the CMT-20) is marketed as a host-seeking mosquito trap, designed to attract anthropophagic mosquito species.

## MATERIALS AND METHODS

### Sampling devices

The body of the CDC miniature light trap (model 1912; John W. Hock Co., Gainesville, FL) consists of Plexiglas® tubing, which houses a 6.3-V light bulb, a direct-current motor, and a fan blade. A motorcycle, lead-acid, 6-V battery provides the necessary power. A detachable, flat-topped, plastic lid covers the body of the trap to protect the operating mechanism. Insects attracted to the light are drawn through the fan blade into a fine mesh collection cup that hangs from the bottom of the tubing. Traps and accompanying plastic thermoses containing 2 kg dry ice (as a source of $CO_2$) were hung from trees approximately 1.5 m above the ground.

The BG-Sentinel (BioGents GMbH, Regensburg, Germany) (Geier et al. 2004, Krockel et al. 2006, Maciel de Feitas et al. 2006, Rose et al. 2006, Williams et al. 2006) mosquito trap mimics convection currents created by a human body, employs attractive visual cues, and releases attractants through a large surface area. The BG-Sentinel trap is normally used in combination with a novel attractant lure, the solid BG-Lure, which consists of a combination of nontoxic substances that are specifically found on human skin, including ammonia, lactic acid, and fatty acids. Each lure remains active for up to 5 months and is secured into a special pouch in the interior of the trap (BioGents AG 2007a).

The BG-Sentinel trap is essentially a collapsible pop-up container with white gauze covering the opening. The trap has a diameter of 36 cm and a height of 40 cm. In the middle of the gauze cover, air is drawn into the trap through a black catch pipe by an electrical fan, drawing approaching mosquitoes into a collection bag. The air then exits the trap through the white gauze, generating ascending currents. These are similar to convection currents produced by a human host in their direction, their geometrical structure, and, due to the addition of the BG-Lure, also in their chemical composition (BioGents AG 2007b). Traps were placed on the ground, and accompanying plastic thermoses containing 2 kg dry ice (as a source of $CO_2$) were hung approximately 30 cm above the traps.

The CMT-20 trap is a late prototype of the Zumba mosquito trap ISCA Technologies, Inc., Riverside, CA (Coler 2006). The trap combines a wide variety of visual and chemical stimuli that are used by host-seeking mosquitoes. These stimuli include color (green and black), size (the trap can be lengthened up to 120 cm by altering the length of the black profile skirt at the bottom of the trap), shape, and odor plume dissemination and direction. Chemical stimuli include a chemical lure (the SkinLure™ ISCA Technologies, Inc., Riverside, CA), which mimics the profile of human skin, and $CO_2$ (Coler 2005). The SkinLure needs replacing frequently, and during these field trials the solution was replenished every 3 days. The SkinLure receptacle (an open Tupperware® container [Tupperware, Orlando, FL] resting on a cloth shelf inside the trap) contains a sponge, which is saturated every 3rd day with 200 ml SkinLure and, on the other days, with a similar amount of water to account for evaporation of the SkinLure.

The CMT-20 can be hooked up to a tank of compressed gas, which releases an even plume of $CO_2$ over the duration of the trapping period. In order to be consistent, the CMT-20 was not used with the $CO_2$ gas hookup in this study, and was hung, like the other traps, with an accompanying plastic thermos filled with 2 kg dry ice (as a source of $CO_2$). All the CMT-20 traps were hung so that the height of the air intake tube was at the same height as the air inlet of the CDC traps, approximately 1.5 m above the ground.

### Experimental design and study site

Both traps were evaluated in the manner in which they were sold (i.e., trap plus associated lure) as well as with and without a source of $CO_2$. The $CO_2$-baited CDC trap is the industry standard for host-seeking mosquitoes and was used as a gold standard against which to compare the novel traps. Five replicates of a 5 × 5 Latin square experimental design were used to evaluate the various trap configurations, resulting in a total of 25 replicates for each of the 5 trap configurations. The 5 configurations were

1. BG-Sentinel (with BG-Lure),
2. BG-Sentinel (with BG-Lure) + $CO_2$,
3. CMT-20 (with SkinLure),
4. CMT-20 (with SkinLure) + $CO_2$,
5. CDC + $CO_2$.

For each replicate, trapping occurred over a period of 5 consecutive days, during which each trap type and configuration was rotated through 5 predetermined trapping stations located 30 m apart. A 1.5 × 2.0-m tarpaulin was temporarily installed at a height of 2.0 m at each trapping station to serve as a rain barrier, underneath which a wire was strung to hang the CMT-20 and CDC traps (the BG-Sentinel traps rested on the ground). All replicates were conducted in a

Table 1. Numbers (mean and proportion) of female mosquitoes collected in 24-h trapping periods using the CDC miniature light trap and 2 novel mosquito traps.

| | CDC[1] | | BG[2] | | CMT[2] | | CMT[3] | | BG[3] | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Mean | % | Mean | % | Mean | % | Mean | % | Mean | % |
| *Aedes albopictus* | 1.75 | 24.85 | 58.46 | 73.19 | 4.13 | 21.85 | 0.88 | 41.51 | 11.21 | 89.37 |
| *Ae. vexans* | 0.54 | 7.69 | 2.08 | 2.61 | 0.21 | 1.10 | 0.04 | 1.89 | 0.00 | 0.00 |
| *Anopheles punctipennis* | 1.42 | 20.12 | 6.33 | 7.93 | 0.50 | 2.65 | 0.04 | 1.89 | 0.04 | 0.33 |
| *Culex* spp. | 0.33 | 4.73 | 1.17 | 1.46 | 4.38 | 23.18 | 0.40 | 18.87 | 0.08 | 0.66 |
| *Cx. erraticus* | 0.46 | 6.51 | 0.38 | 0.47 | 1.04 | 5.52 | 0.12 | 5.66 | 0.04 | 0.33 |
| *Cx. pipiens* | 1.04 | 14.79 | 5.38 | 6.73 | 4.88 | 25.83 | 0.16 | 7.55 | 0.38 | 2.99 |
| *Cx. restuans* | 0.96 | 13.61 | 1.00 | 1.25 | 1.29 | 6.84 | 0.12 | 5.66 | 0.38 | 2.99 |
| *Cx. territans* | 0.04 | 0.59 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Ochlerotatus japonicus* | 0.04 | 0.59 | 0.25 | 0.31 | 0.04 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Oc. triseriatus* | 0.38 | 5.33 | 4.42 | 5.53 | 2.29 | 12.14 | 0.24 | 11.32 | 0.33 | 2.66 |
| *Psorophora ferox* | 0.00 | 0.00 | 0.42 | 0.52 | 0.13 | 0.66 | 0.00 | 0.00 | 0.08 | 0.66 |
| *Toxorhynchites rutilus* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 5.66 | 0.00 | 0.00 |
| *Uranotaenia sapphirina* | 0.08 | 1.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 7.04 | 100.00 | 79.88 | 100.00 | 18.88 | 100.00 | 2.12 | 100.00 | 12.54 | 100.00 |

[1] Trap used with 2 kg dry ice only.
[2] Traps used with lure (BG-Sentinel™ with BG-Lure or CMT-20™ with SkinLure™) and 2 kg dry ice.
[3] Traps used with lure (BG-Sentinel with BG-Lure or CMT-20 with SkinLure) only.

wooded transitional habitat located behind the Fairfax County Health Department in Northern Virginia, found between forest and residential or business areas. This area has been used extensively for mosquito surveillance in previous years and supports a mosquito population including *Ae. albopictus* and other WNV vector species.

Traps ran Monday through Saturday of each week, with the last traps of each replicate picked up on Saturday mornings. Trapping began on July 31, 2006, and continued almost daily for the following 5 wk. This period was chosen because it coincided with the peak abundance of *Ae. albopictus*, as determined by routine CDC light-trap data from previous years. Each trap was set in the morning and picked up after a period of 24 h. Mosquitoes were immediately anesthetized with triethylamine and identified to species with the aid of dissecting microscopes.

### Statistical analysis

In order to evaluate the effectiveness of the novel traps, the mean collection data were log ($x$ + 1)-transformed prior to analysis of variance (ANOVA) with Tukey's post hoc testing using SPSS release 11.0.1 (SPSS, Inc., Chicago, IL). To measure the efficiency of the novel traps, the *Ae. albopictus* proportion data from the 5 configurations were compared using contingency tables and the chi-square ($\chi^2$) statistic with Bonferroni post hoc correction (Riffenburgh 2006).

## RESULTS

### Trap efficiency

The efficiency, or specificity, of the traps in collecting *Ae. albopictus* was assessed by comparing the overall proportion of *Ae. albopictus* collected among the 5 trap configurations. Table 1 shows the proportion of *Ae. albopictus,* as well as the mean number of *Ae. albopictus,* collected per 24-h trapping period in each of the trap configurations. Overall, the BG-Sentinel collected the highest proportions of *Ae. albopictus,* making it the most efficient trap (of the traps evaluated) for collecting *Ae. albopictus*. When used with $CO_2$, 73.19% of the mosquitoes collected using the BG-Sentinel (with BG-Lure) were *Ae. albopictus.* Without $CO_2$, 89.37% of the mosquitoes collected in the BG-Sentinel (with BG-Lure) were *Ae. albopictus.* The difference between these proportions was significant at the 5% level.

Although statistical analysis showed that there was an overall significant difference in the proportions of *Ae. albopictus* collected with the different trap configurations ($\chi^2 = 169.38$, $P < 0.0001$), individual comparisons using Bonferroni's post hoc correction showed that there was no significant difference between the proportion of *Ae. albopictus* collected with the $CO_2$-baited CDC trap and the 2 CMT-20 trap configurations.

### Trap effectiveness

The effectiveness of each of the 5 trap configurations (as measured by the mean number of female *Ae. albopictus* per 24-h trapping period) is shown in Fig. 1 and Table 1. When used with $CO_2$, the BG-Sentinel (with BG-Lure) collected the highest mean number of *Ae. albopictus* (58.46) per 24-h trapping period, with a range of 13–131. Without a source of $CO_2$, the BG-Sentinel (with BG-Lure) was the second most effective of the 5 trap configurations and collected a mean of 11.21 *Ae. albopictus,* with a range of 1–50 *Ae. albopictus*

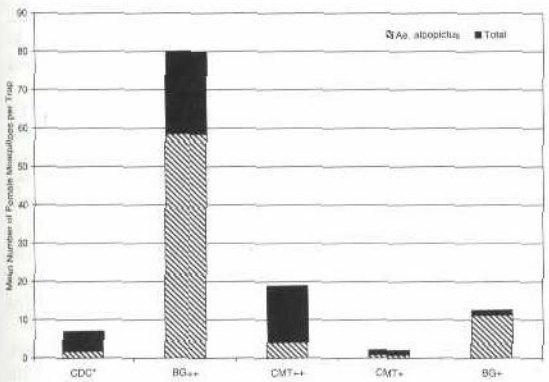


Fig. 1. Mean number of female *Ae. albopictus* collected in 24-h trapping periods as a proportion of the total number of mosquitoes collected using the CDC miniature light trap and 2 novel host-seeking mosquito traps (the BG-Sentinel™ and the CMT-20™).*, trap used with 2 kg dry ice only. +, traps used with lure (BG-Sentinel with BG-Lure or CMT-20 with SkinLure™) only. ++, traps used with lure (BG-Sentinel with BG-Lure or CMT-20 with SkinLure) and 2 kg dry ice.

per trapping period. The CMT-20 (with SkinLure) and $CO_2$, the CMT-20 (with SkinLure), and the $CO_2$-baited CDC trap collected (respectively) a mean of 4.13, 0.88, and 1.75 *Ae. albopictus* per 24-h trapping period.

The mean number of *Ae. albopictus* collected was significantly affected by trap type configuration ($F = 62.22$, $P < 0.0001$) but was not affected by trap location ($F = 0.827$, $P = 0.511$) or by trap day ($F = 1.24$, $P = 0.298$). Using Tukey's post hoc test to perform multiple comparisons of the mean number of *Ae. albopictus* showed that with or without $CO_2$, the BG-Sentinel (with BG-Lure) collected significantly more *Ae. albopictus* than the $CO_2$-baited CDC light trap and both configurations of the CMT-20 trap. With $CO_2$, the BG-Sentinel (with BG-Lure) collected 33 times as many *Ae. albopictus* as the CDC trap. Without $CO_2$, the BG-Sentinel (with BG-Lure) collected 6 times as many *Ae. albopictus* as the CDC trap. The addition of $CO_2$ increased the trapping effectiveness by almost 400%.

Comparisons showed that neither of the CMT-20 trap configurations performed any differently in terms of the mean number of *Ae. albopictus* collected per 24-h trapping period, than the industry standard $CO_2$-baited CDC miniature light trap.

## DISCUSSION

These results demonstrate that the BG-Sentinel (with BG-Lure) is a highly efficient and effective tool for collecting *Ae. albopictus* in Northern Virginia. With or without a source of $CO_2$, the BG-Sentinel (with BG-Lure) performed significantly better than the $CO_2$-baited CDC trap in terms of the number and proportion of *Ae. albopictus* collected, and it is anticipated that this trap will perform similarly in other areas where *Ae. albopictus* is highly abundant. This trap is an invaluable addition to mosquito surveillance and control programs, especially to those interested in furthering their understanding of the role *Ae. albopictus* plays in arbovirus transmission. In addition to WNV, *Ae. albopictus* is an important vector (in the Americas) of eastern equine encephalitis and dengue virus. Incorporating the BG-Sentinel trap into surveillance programs for these and other arboviruses might lead to a better understanding of *Ae. albopictus* dynamics.

In order to determine the true value of the BG-Sentinel trap in assessing WNV transmission, further research is needed to determine the parity status of mosquitoes, particularly *Ae. albopictus*, collected in the field. A trap that attracts primarily nulliparous mosquitoes is unlikely to collect many arbovirus-infected mosquitoes, and any infection rate calculated from nulliparous mosquitoes will lead to an underestimate of the true infection rate.

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