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 (CO2)-baited Centers for Disease Control and Prevention (CDC) miniature light trap. When used with CO2, the BG-Sentinel (with BG-Lure) collected 33 times more female Ae. albopictus per 24-h trapping period than did the CO2-baited CDC light trap. Without CO2, the BG-Sentinel (with BG-Lure) still collected over 6 times as many female Ae. albopictus as the CO2-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 CO2 and without CO2. The CMT-20 (with SkinLure™) collected significantly more Ae. albopictus when used with CO2 than without CO2, but did not collect significantly more Ae. albopictus than the CO2-baited CDC light trap. The proportion of Ae. albopictus collected in the CMT-20 with CO2 and without CO2 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 (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 CO2-baited CMT-20 trap performed better than the CO2-baited CDC trap (Coler 2005). Similar trials were conducted in Texas, where the CMT-20 outper-
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 CO2) were hung 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 30 days 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 CO2) were hung approximately 30 cm above the traps.

The CMT-20 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 CO2 (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 CO2 over the duration of the trapping period. In order to be consistent, the CMT-20 was not used with the CO2 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 CO2). 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 CO2. The CO2-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) + CO2,
3. CMT-20 (with SkinLure),
4. CMT-20 (with SkinLure) + CO2,
5. CDC + CO2.

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.

<table>
<thead>
<tr>
<th>Species</th>
<th>CDC(^1)</th>
<th>BG(^1)</th>
<th>CMT(^2)</th>
<th>CMT(^3)</th>
<th>BG(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>%</td>
<td>Mean</td>
<td>%</td>
<td>Mean</td>
</tr>
<tr>
<td>Aedes albopictus</td>
<td>1.75</td>
<td>24.85</td>
<td>58.46</td>
<td>73.19</td>
<td>4.13</td>
</tr>
<tr>
<td>Ae. vexans</td>
<td>0.54</td>
<td>7.69</td>
<td>2.08</td>
<td>2.61</td>
<td>0.21</td>
</tr>
<tr>
<td>Anopheles punctipennis</td>
<td>1.42</td>
<td>20.12</td>
<td>6.33</td>
<td>7.93</td>
<td>0.50</td>
</tr>
<tr>
<td>Culex spp.</td>
<td>0.33</td>
<td>4.73</td>
<td>1.17</td>
<td>1.46</td>
<td>4.38</td>
</tr>
<tr>
<td>Cx. erraticus</td>
<td>0.46</td>
<td>6.51</td>
<td>0.38</td>
<td>0.47</td>
<td>1.04</td>
</tr>
<tr>
<td>Cx. pipiens</td>
<td>1.04</td>
<td>14.79</td>
<td>5.38</td>
<td>6.73</td>
<td>4.88</td>
</tr>
<tr>
<td>Cx. restuans</td>
<td>0.96</td>
<td>13.61</td>
<td>1.00</td>
<td>1.25</td>
<td>1.29</td>
</tr>
<tr>
<td>Cx. territans</td>
<td>0.04</td>
<td>0.59</td>
<td>0.00</td>
<td>0.00</td>
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</tr>
<tr>
<td>Ochlerotatus japonicus</td>
<td>0.04</td>
<td>0.59</td>
<td>0.25</td>
<td>0.31</td>
<td>0.04</td>
</tr>
<tr>
<td>Cx. triseriatus</td>
<td>0.38</td>
<td>5.33</td>
<td>4.42</td>
<td>5.53</td>
<td>2.29</td>
</tr>
<tr>
<td>Psorophora ferox</td>
<td>0.00</td>
<td>0.00</td>
<td>0.42</td>
<td>0.52</td>
<td>0.13</td>
</tr>
<tr>
<td>Toxorhynchites rubitus</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Uranotaenia sapphirina</td>
<td>0.08</td>
<td>1.18</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td>7.04</td>
<td>100.00</td>
<td>79.88</td>
<td>100.00</td>
<td>18.88</td>
</tr>
</tbody>
</table>

\(^1\) 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.

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 (Z\(^2\) = 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.

**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. 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.
per trapping period. The CMT-20 (with SkinLure) and CO$_2$, the CMT-20 (with SkinLure), and the CO$_2$-bailed 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$_2$-bailed 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$_2$-bailed 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$_2$-bailed 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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