Host-Seeking Height Preferences of *Aedes albopictus* (Diptera: Culicidae) in North Central Florida Suburban and Sylvatic Locales

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J. Med. Entomol. 46(4): 900–908 (2009)

ABSTRACT The response of *Aedes albopictus* to the BG-Sentinel, Omni-directional-Fay-Prince, and Mosquito MagnetX traps was evaluated in four suburban and four sylvatic habitats in north-central Florida to ascertain potential height preference of this species. These traps, which are primarily designed to attract diurnal mosquitoes, were set at 1 and 6 m and were evaluated during 40 trapping periods over 4 mo. We collected 45,640 mosquitoes, representing 26 species from 10 genera, the most common being *Aedes albopictus*, *Ae. vexans*, *Coquilletidia perturbans*, *Culex nigripalpus*, *Aedes infirmatus*, *Ae. triseriatus*, and *Psorophora ferox*. Although significantly more *Ae. albopictus* were captured at 1 m above ground than at 6 m, fewer were captured in sylvatic habitats than suburban habitats. Although not statistically different, the BG-Sentinel caught more *Ae. albopictus* compared with the other two traps regardless of locale. These results suggest that, although *Ae. albopictus* was captured as high as 6 m, the majority seek hosts at or below 1-m heights. This further supports prior research that, although *Ae. albopictus* has been shown to disseminate West Nile virus, it has not been implicated as a major vector for the virus, which is likely because of its propensity to feed on ground-dwelling hosts. The study also shows how trap type, trap heights, and environments influence sampling estimates when determining species abundance.

KEY WORDS mosquitoes, traps, surveillance, vertical distribution, semiochemicals

Aedes albopictus (Skuse) is an invasive mosquito that was introduced into Florida in 1986 (Peacock et al. 1988) and has quickly become established throughout most of the state. A persistent daytime biter on humans, it has become a severe nuisance in residential suburban areas. More importantly, it has been reported to transmit 23 arboviruses, including La Crosse and West Nile (WN) (Moore and Mitchell 1997, Gerhardt et al. 2001, Turell et al. 2001). The 2002 dengue epidemic on the Hawaiian island of Maui (Effler et al. 2005) and recent outbreaks of chikungunya (CHIK) in Italy, India, and islands throughout the Indian Ocean (Rezza et al. 2007) show how these viruses may be introduced into the continental United States and reaffirms that *Ae. albopictus* is a competent vector. Field-collected *Ae. albopictus* from Palm Beach County, FL, were recently successfully infected in the laboratory with CHIK (La Réunion strain; LR2006-OPY1) and showed infection and dissemination rates as high as 100% (Reiskind et al. 2008). Given the prevalence and competence of *Ae. albopictus* to transmit CHIK, the introduction and establishment of CHIK in Florida and throughout the range of *Ae. albopictus* in the United States is a real possibility. Furthermore, worldwide outbreaks of dengue continue to rapidly rise, placing additional burdens to develop rapid surveillance tools to access populations of *Ae. aegypti* L. and *Ae. albopictus* without using risky procedures such as human landing counts.

Adult mosquito traps are important surveillance tools used not only to assess mosquito populations before and after control operations but also to provide critical information regarding the potential for transmission of viruses (Chan 1985). Adult mosquito trapping including programs designed to collect *Ae. alboipictus* are primarily conducted near ground level, potentially missing important mosquito activity occurring in the tree canopy (Anderson et al. 2006). Also, most surveillance programs use CDC miniature light traps that are not effective in capturing day flying *Stegoymia* (*Aedes*) spp. (Service 1993). *Ae. albopictus*, like other diurnal mosquitoes, use visual cues such as bright colors, patterns, UV reflectance, and movement to target their hosts (Allan et al. 1987). The use of visual attractants, specifically black and white patterns, has been a proposed method for attracting mosquitoes (Haufe 1964). Fay (1968) first described using a daytime mosquito trap to target resting *Ae. aegypti* L.

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Further development of this configuration by Fay and Prince (1970) resulted in a box-like trap with contrasting black and white sides. Wilton and Kloter (1985) later developed a lighter black cylindrical-shaped trap that was effective at sampling female and male *Ae. aegypti.*

Several traps are effective at collecting *Ae. albopictus* and have been used in surveillance studies. These include the BG-Sentinel (BG; BioGents, Regensburg, Germany) (Meeraus et al. 2008), Omni-directional Fay-Prince (ODFP; John Hock, Gainesville, FL) (Jensen et al. 1994), and Mosquito Magnet X (MM-X; American Biophysics, North Kingston, RI) (Hoel 2005). However, little data exist concerning their performance at varying heights and various environments. Additionally, no information exists on host-seeking preferences of *Ae. albopictus* at ground level versus the mature tree canopy in Florida.

It is known that *Ae. albopictus* will feed on a wide range of hosts including birds, but prefers mammals, especially in suburban settings (Richards et al. 2006). Information gained from the vertical distribution of host-seeking *Ae. albopictus* would help explain how virus transmission from mosquitoes to birds and mammals, including humans can occur. This study has two objectives: (1) evaluate the BG, MM-X, and ODFP traps at two heights to determine the influence of height on *Ae. albopictus* host-seeking activity in suburban and sylvatic environments and (2) determine the effectiveness of the BG trap in capturing *Ae. albopictus* in suburban and sylvatic environments in north-central Florida.

Materials and Methods

Site Selection. Tests were conducted from May to September 2007. At suburban locales, four residential properties (29°37.837′ N, 82°27.800′ W; 29°34.248′ N, 82°24.644′ W; 29°39.019′ N, 82°23.234′ W; 29°42.481′ N, 82°24.745′ W) were in or near the city limits of Gainesville, FL. Suburban locales met four criteria: (1) residents made frequent complaints of mosquitoes biting during the day; (2) sites had thickly wooded lots surrounding the residential property; (3) sites support populations of *Ae. albopictus;* and (4) sites were secured to prevent trap theft. Suburban sites were separated by >3.2 km and contained a mixture of shrubs and trees, namely azalea (*Rhondendron* spp.), oleander (*Nerium oleander* L.), Indian hawthorn (*Rahphiolepis indica* L.), live oak (*Quercus virginiana* P. Mill), water oak (*Quercus nigra* L.), and longleaf pine (*Pinus palustris* P. Mill).

Four sylvatic locales (29°43.574′ N, 82°27.252′ W; 29°44.048′ N, 82°26.458′ W; 29°43.574′ N, 82°27.233′ W; 29°44.238′ N, 82°28.138′ W) were distributed throughout San Felasco Hammock Preserve State Park, Alachua Co., FL. A research and collecting permit (02130742) was granted (to P.J.O.) by the Florida Department of Environmental Protection to collect mosquitoes within the park premises. Unpublished data were made in September 2006 to verify the existence of *Ae. albopictus* in sylvatic sites. Security and park regulations mandated that all traps be placed at a minimum of 40 m from artificial trails. Traps were placed in forest-fringe areas or areas with large openings in the canopy; these usually included areas around sinkholes and swamps. Sylvatic locales were separated by at least 0.8 km and contained a mixture of mature hardwood and pine trees, namely live oak (*Quercus virginiaina* P. Mill), water oak (*Quercus nigra* L.), laurel oak (*Quercus laurifolia* Michx.), longleaf pine (*Pinus palustris* P. Mill), and slash pine (*Pinus elliottii* Engelm).

Traps and Baits. The BG trap is a white, light-weight, collapsible, bucket-like device with its upper opening covered with mesh. Mosquitoes are drawn into the trap by a 12-V DC fan. A black plastic tube (12 by 12 cm) is fitted into the top center of the trap and empties into a catch bag. To lure diurnal mosquitoes, white and black colors are used as visual cues in combination with a synthetic bait that mimics skin secretions (Kröckel et al. 2006). The synthetic bait, BG-Lure (BioGents), consists of 2 m of coiled 4.75-mm-ID silicon tubing (containing 15 ml of lactic acid), 50 cm of 0.4-mm-ID high-density polyethylene tubing (2 ml of caproic acid), and a slow release ammonia acrylic fibrous tablet as described in Williams et al. (2006). The trap design, in combination with the lure, creates ascending currents that mimic convection currents created by the human body (Kröckel et al. 2006). The BG trap was originally designed to capture *Ae. aegypti* inside or close to residential sites (D. Kline, personal communication). Our study required these traps to be kept in outdoor environments over long durations without shelter. To prevent rain damage to circuits and motor components, an aluminum pan (36 cm diameter) was attached 30 cm above the trap entrance with two nylon cords and secured to the handles of the trap. Blue smoke 2B (Signal Company, Spotswood, NJ) was used to highlight air flow to ensure unobstructed suction.

The MM-X trap uses a counter-flow concept that discharges an attractant plume of carbon dioxide at the trap entrance to attract and capture mosquitoes (Kline 1999). This trap consists of two fans, an 80-mm intake fan and a 40-mm exhaust fan, that are inserted into an oval-shaped clear PVC shell as described in Hoel (2005). An advantage in using the MM-X trap over other mosquito traps is that captured insects cannot reach the intake fan and are subsequently rarely damaged.

The ODFP trap uses contrasting black and white metal panels that serve as a visual attractant (Fay and Prince 1970). The trap is 2.7 kg in weight and is comprised of four extending panels (40.5 by 17.5 cm) set at 90° angles to each other and used to funnel mosquitoes into the center of the trap, where they are pulled down through an opening by a fan (Jensen et al. 1994). The trap is covered by a 40-cm^2 white sheet of metal set 10 cm above the trap opening.

All traps were baited with CO_2 from a 9-kg compressed gas cylinder with a flow rate of 500 ml/min. A Gilmont Accucal flowmeter (Gilmont Instrument, Barrington, IL) was used at every rotation to verify the accuracy of CO_2 discharge. Flow rates were regulated using a 15-psi single stage regulator equipped with microregulators and an inline filter (Clarke Mosquito Control, Roselle, IL). CO_2 flowed from the cylinder to the trap using 6.4-mm-diameter black plastic tubing (Clarke Mosquito Control and American Biophysics).

All traps were baited with a BG-Lure (batch ML066A). Lures were replaced after 2 mo to ensure that bait attractant was not degraded by heat and humidity as recommended by the manufacturer. Paperclips were used to attach the lure to the CO_2 outflow area of the ODFP and MM-X traps. Unlike the MM-X trap, ODFP and BG traps do not have a CO_2 port attachment. Therefore, CO_2 tubing was positioned near the ODFP fan intake and secured with a plastic tie. CO_2 tubing was inserted into the top of the BG trap with the opening placed near the lure pocket and secured using a white Velcro strap.

All traps were powered by rechargeable gel cell batteries (Battery Wholesale Distributors, Georgetown, TX) that were replaced every 48 h. The BG and MM-X traps used a 12-V, 12-ampere-hour (A-h) battery, whereas the ODFP trap used a 6-V, 12-A-h battery. At the start of each trapping period, adhesive tape was inversely folded over with the adhesive side facing out to act as a sticky band and attached to the top of traps and power cords to prevent ants from consuming captured mosquitoes.

Trap Placement. Each of the three traps was placed at one height (either 1 or 6 m) per site and randomized at every collection period. Traps were placed underneath trees in shaded areas, because Peacock et al. (1988) observed traps placed in shaded areas caught 11% more adult *Ae. albopictus* than those placed in partial shade. Traps within each site were set at least 20 m from each other and at least 10 m from residences.

Two methods of trap suspension were used. Traps placed at 1 m were suspended from a shepherds hook. Traps placed in tree canopies at heights of 6 m required a pulley system to allow the trap to be raised and lowered for collection. A tree branch was selected that was 7–8 m in height and capable of supporting all three types of traps. A modified slingshot method (Novak et al. 1981) was used to place the pulley system into the canopy. A modified system using two ropes was used (Lundström et al. 1996). A 25-m, 6.35-mm-diameter interwoven nylon rope was attached to a 25-mm metal loop that was drawn through the pulley. To accurately determine height, a second rope containing 1-m markings was inserted through the loop and suspended from the canopy. Because these traps differ in the position of the trap entrance (bottom or top entry), trap placement was adjusted to ensure that all trap openings were at either 1 or 6 m in height.

Traps were set between 0800 and 1100 hours and left in place for 48 h (one trapping period = 2 trap nights), at which time mosquitoes were collected. Traps were repositioned for each subsequent trapping period. Four consecutive trapping periods (2 wk) took place at each locale (suburban or sylvatic), after which traps were removed and moved between suburban or sylvatic locales accordingly. The absence of traps for 2 wk between the two environments was designed to mitigate any negative impact of trapping on the mosquito population. Trapping occurred from 16 May to 09 June, 13 June to 7 July, 11 July to 4 August, 8 August to 1 September, and 5 to 29 September for a total of five trials resulting in 20 trapping periods (40 trap nights) per locale.

Environmental conditions within each site, including temperature and light intensity, were monitored using a HOBO pendant temperature/light data logger (Onset Computer Corporation, Bourne, MA) with 30-min recordings. Precipitation was measured at the Department of Agronomy Forage Research Unit in Gainesville, FL, and subsequent data were retrieved from the Florida Automated Weather Network, University of Florida. Mosquitoes were immobilized at −20°C for 5 min, dispensed into 1.5-ml plastic microcentrifuge tubes, and frozen (−20°C) for later identification to species using Darsie and Morris (2003).

Statistical Analysis. A randomized block design with factorial treatments was used to test differences in mosquito capture between traps, heights, and locales. All traps were rotated after each trapping period within sites to eliminate location and trap bias. Data were transformed with $\log_{10}(n + 1)$ and analyzed using an analysis of variance (ANOVA) model to detect differences between the fixed effects. Only female mosquitoes were used for statistical analyses. Trap type, height, site, and locale were fixed effects in the model. The model also included the trap type by trap height interaction effect. Where interactions were found to be significant, the interaction error term was used to calculate *P* values. Statistical analyses were conducted using PROC GLM conducted on SAS software, version 9.1 (SAS Institute, Cary, NC). Multiple mean comparisons were made with the Ryan-Einot-Gabriel-Welsh (REGW) multiple range test (α = 0.05).

Results

Forty trap periods (80 trap nights), which incorporated 20 suburban and 20 sylvatic trappings over five trials, resulted in a total capture of 45,640 mosquitoes, representing 26 species from 10 genera (Table 1). Although inverted adhesive tape proved effective at preventing ant access to the traps, occasionally large numbers of ants infested the traps and destroyed the mosquitoes. Additional data were lost because of trap and battery failure. Data from these traps were discarded and treated as missing values.

In suburban locales, 23 species were captured at 1-m height, whereas only 14 species were captured at 6-m height (Table 1). Traps placed in sylvatic locales captured 18 and 17 species at 1 and 6 m, respectively. Trap collections from suburban sites represented 71% of the total capture. The following nine species composed 99% of the total collection and were subsequently analyzed: *Ae. albopictus*, *Ae. vexans* (Meigen), *Anopheles crucians* Wiedemann, *Coquilletidia perturbans* Dyar, *Culex nigripalpus* Say, *Cx. erraticus* (Dyar and

Table 1. Total mosquitoes captured at 1- and 6-m heights in suburban and sylvatic locales from May to Sept. 2007 in Gainesville, FL

Species	Locale				Total (%)
	Suburban		Sylvatic		
	1 m	6 m	1 m	6 m	
Culex nigripalpus	7,667	14,874	2,871	6,326	31,738 (69.5)
Aedes albopictus	4,164	564	73	17	4,818 (10.5)
Coquillettidia perturbans	1,057	1,147	269	91	2,564 (5.6)
Ae. vexans	862	174	1,276	60	2,372 (5.1)
Ae. infirmatus	448	85	800	91	1,424 (3.1)
Psorophora ferox	634	33	521	21	1,209 (2.6)
Cx. erraticus	120	146	202	39	507 (1.1)
Anopheles crucians	30	6	275	35	346 (0.8)
Ae. triseriatus	123	33	86	100	342 (0.8)
Cx. salinarius	23	50	9	7	89 (0.2)
Mansonia titillans	20	28	2	3	53 (0.1)
Ps. columbiae	16	9	6	1	32 (<0.1)
Toxorhynchites rutilus	4	5	9	6	24 (<0.1)
Cx. quinquefasciatus	16	0	4	2	22 (<0.1)
An. quadrimaculatus	16	0	1	1	18 (<0.1)
Wyeomyia mitchelii	16	0	0	0	16 (<0.1)
An. punctipennis	1	2	9	2	14 (<0.1)
Orthopodomyia signifera	0	0	2	9	11 (<0.1)
Ae. taeniorhynchus	8	2	0	0	10 (<0.1)
An. barberi	1	0	4	2	7 (<0.1)
Ps. howardii	2	1	4	0	7 (<0.1)
Cx. territans	5	0	0	0	5 (<0.1)
Ps. ciliata	2	0	2	0	4 (<0.1)
Ae. atlanticus	2	0	1	0	3 (<0.1)
Wy. smithii	3	0	0	0	3 (<0.1)
Culiseta inornata	0	0	0	2	2 (<0.1)
Total	15,240	17,159	6,426	6,815	45,640

Species listed in descending order of the total numbers of each species collected.

Traps used were the BG-Sentinel, Mosquito Magnet-X, and the Omni-directional Fay-Prince trap. Traps were baited with CO_2 at a flow rate of rate of 500 ml/min and a BG-Mesh lure. Total trapping periods = 40 (1 trapping period = 48 h).

Knab), *Ae. infirmatus* (Dyar and Knab), *Ae. triseriatus* (Say), and *Psorophora ferox* (von Humboldt).

***Aedes albopictus*.** Few *Ae. albopictus* were captured during the months of May and early June. However, by early July, *Ae. albopictus* had been collected from all sites. Captures of *Ae. albopictus* peaked in mid-July when a total of 1,503 were collected. Trap captures of *Ae. albopictus* were fewest during May (0.65 ± 0.2). Significantly more *Ae. albopictus* were collected during June (6.5 ± 1.2) and September (7.6 ± 2.1), with peak collections occurring during July (16.7 ± 3.7) and August (11.1 ± 2.4; $F = 29.08$; df = 4,425; $P < 0.001$).

Aedes albopictus (males and females) comprised >10% of the capture (4,818) (Table 1) and was the second most commonly captured mosquito. Males comprised 21.7% of the *Ae. albopictus* capture. No significant difference was detected between trap capture means (Table 2). Significantly more *Ae. albopictus* were trapped in suburban locales (16.4 ± 1.9) compared with sylvatic locales (0.4 ± 0.1; $F = 500.50$; df = 1,425; $P < 0.001$; Fig. 1). Significant differences were also detected between those trapped at 1 m (14.5 ± 1.9) compared with 6 m (2.3 ± 0.3; $F = 120.22$; df = 1,425; $P < 0.001$; Fig. 2). A greater percentage (87%) of female *Ae. albopictus* were captured at 1 m versus traps placed at 6 m. Only 2.2% (male and female) of this species were captured in sylvatic locales. Sites within locales also proved to be highly significant with respect to *Ae. albopictus* collections ($F = 27.78$; df = 6,425; $P < 0.0001$). Within the sylvatic locales, one site accounted for 50% of *Ae. albopictus* captured. This site was in closer proximity to Interstate 75 and residential areas than the other three sylvatic sites. Seventy-five percent of all *Ae. albopictus* trapped in suburban locales were from two sites.

Other Mosquito Species. The BG trap significantly outperformed the MM-X and ODFP traps at capturing *Cx. nigripalpus*, *Cq. perturbans*, *Ps. Ferox*, and *Ae. triseriatus* (Table 2). *Cx. nigripalpus* exhibited an increased attraction for the MM-X (53.5 ± 14.9) over the ODFP (28.5 ± 10.7) trap ($F = 51.99$; df = 2,425; $P < 0.0001$).

The most commonly captured mosquito during this study from suburban and sylvatic locales was *Cx. nigripalpus* (Table 1). Significantly more *Cx. nigripalpus* were trapped at 6 m (97.7 ± 23.7) compared with 1 m (46.8 ± 16.2; $F = 40.62$; df = 1,425; $P < 0.0001$; Fig. 2). In addition, significantly more *Cx. nigripalpus* were captured in suburban locales (100 ± 27.4) compared

Table 2. Numbers (mean ± SE) of the nine most common female mosquitoes collected in a trapping period from three traps at 1- and 6-m heights in suburban and sylvatic locales from May to Sept. 2007 in Gainesville, FL[a]

Species	Traps[b]			F	P
	BG	MM-X	ODFP		
Culex nigripalpus	133.1 ± 38.4a	53.5 ± 14.9b	28.5 ± 10.7c	51.99	<0.0001
Aedes albopictus	10.2 ± 2.1a	7.4 ± 1.5a	8.0 ± 1.7a	1.13	0.3230
Coquillettidia perturbans	9.3 ± 1.8a	3.2 ± 0.8b	4.8 ± 1.0b	37.45	<0.0001
Ae. vexans	5.4 ± 1.6b	8.1 ± 2.6a	2.5 ± 0.8c	13.40	0.0021
Ae. infirmatus	4.1 ± 1.3a	2.2 ± 1.2b	3.4 ± 1.0a	6.27	0.0021
Psorophora ferox	6.0 ± 2.0a	0.6 ± 0.3b	1.6 ± 0.7b	23.19	<0.0001
Cx. erraticus	1.6 ± 0.4a	0.7 ± 0.1ab	1.2 ± 0.3ab	2.95	0.0532
An. crucians	0.6 ± 0.3a	1.0 ± 0.3a	0.7 ± 0.3a	1.73	0.1789
Ae. triseriatus	1.2 ± 0.2a	0.4 ± 0.1b	0.7 ± 0.1b	10.40	<0.0001

[a] Means within each row followed by the same letter are not significantly different (Ryan-Einot-Gabriel-Welsh multiple range test), α = 0.05, trap periods = 48 h each; df = 2,425.

[b] Traps were baited with CO_2 at a flow rate of 500 ml/min and a BG-Mesh lure. BG, BG-Sentinel (n = 147); MM-X, Mosquito Magnet X (n = 150); ODFP, Omni-directional Fay-Prince (n = 145).

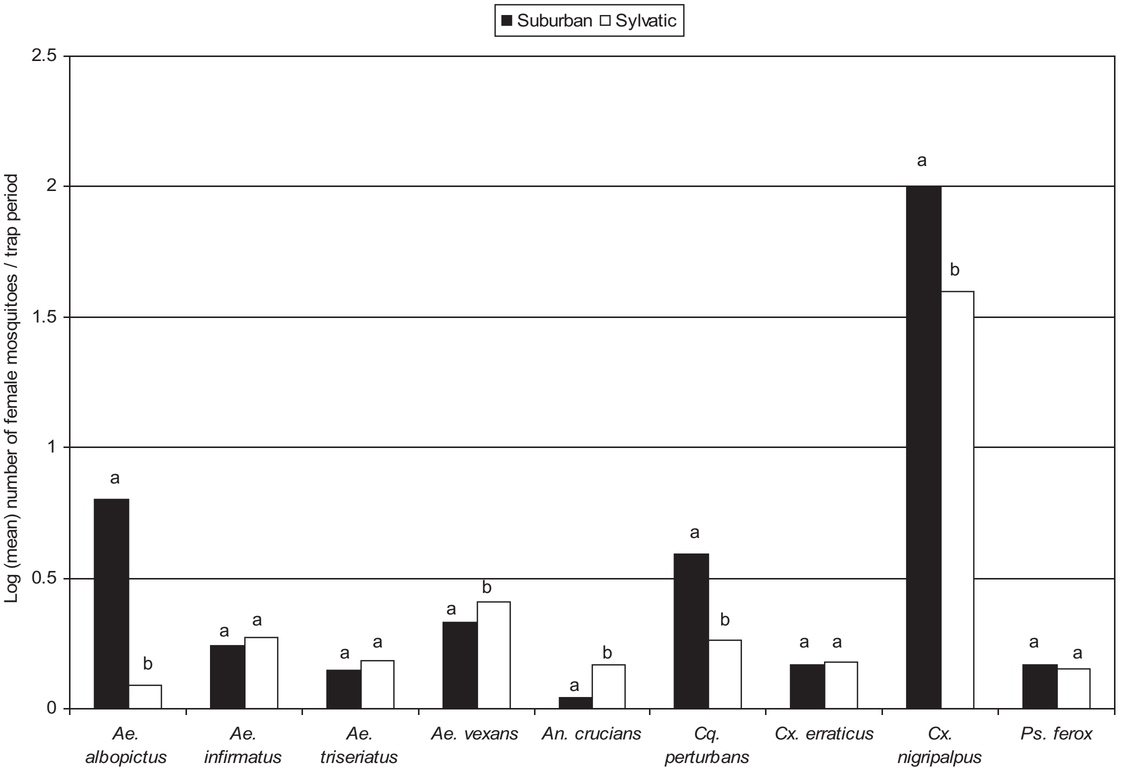

Fig. 1. Mean capture rates of the nine most commonly trapped mosquitoes in suburban and sylvatic locales from May to September 2007 in Gainesville, FL. Means within species with the same letter are not significantly different (REGW multiple range test). *Ae.*, *Aedes*; *An.*, *Anopheles*; *Cq.*, *Coquillettidia*; *Cx.*, *Culex*; *Ps.*, *Psorophora.*

with sylvatic locales (42.6 ± 5.7; $F = 7.49$; df = 1,425; $P = 0.0064$; Fig. 1). Significantly fewer *Cx. nigripalpus* were trapped in the early part of the study, whereas >75% of the capture occurred during the months of August and September ($F = 258.34$; df = 4,425; $P < 0.0001$).

Coquillettidia perturbans was captured in traps at both locales and was the third most commonly captured species (Table 1). Their population levels did not fluctuate throughout the season compared with other mosquitoes in the study. Significantly more *Cq. perturbans* were captured in the BG trap (9.3 ± 1.8) compared with the MM-X (3.2 ± 0.8) and ODFP traps (4.8 ± 1.0; Table 2). The majority of this species (85%) were captured in suburban locales ($F = 37.45$; df = 1,425; $P < 0.0001$).

Significantly more *An. crucians* ($F = 45.13$; df = 1,425; $P < 0.0001$) and *Ae. vexans* ($F = 6.54$; df = 1,425; $P = 0.0109$) were trapped in sylvatic locales (Fig. 1). The BG trap captured significantly more *Ae. triseriatus* (1.2 ± 0.2) and *Ps. ferox* (6.0 ± 2.0) compared with either the MM-X (0.6 ± 0.3, 0.7 ± 0.1) or ODFP (0.4 ± 0.1, 1.6 ± 0.7) traps, respectively (Table 2). However, the MM-X trap captured significantly more *Ae. vexans* (8.1 ± 2.6) compared with the BG (5.4 ± 1.6) and the ODFP (2.5 ± 0.8) traps (Table 2). There was a significant interaction between trap and height for *Ae. vexans* ($F = 6.25$; df = 2,425; $P = 0.0021$) and *Ps. ferox* ($F = 6.44$; df = 2,425; $P = 0.0018$). Although *Toxorhynchites rutilus* (Coquillett) were not captured as often ($n = 24$) compared with other species listed, >91% were trapped with the BG trap. In addition, the majority (62%) were captured in sylvatic locales.

Discussion

Mosquito traps use a variety of lures that may be attractive to specific mosquito species (Service 1993). Our study used traps with black and white colors supplemented with lactic acid, caproic acid, ammonia, and CO_2 to maximize captures of host-seeking *Ae. albopictus.* Our results indicated that traps often elicited mosquito species-specific responses that were dependent on trap type and height placement. The results of this study showed that *Ae. albopictus* populations in north-central Florida are suburban and seek bloodmeals below 6 m. Furthermore, several other species collected showed a distinct height for seeking hosts and were found more often in either suburban or sylvatic locales.

The high percentage (98%; Table 1) of *Ae. albopictus* captured from suburban locales is likely caused by the availability of breeding sites, hosts, or both. Although natural breeding sites (i.e., tree holes) were found supporting *Ae. albopictus* larvae and traps captured adults at every sylvatic locale, the habitat may

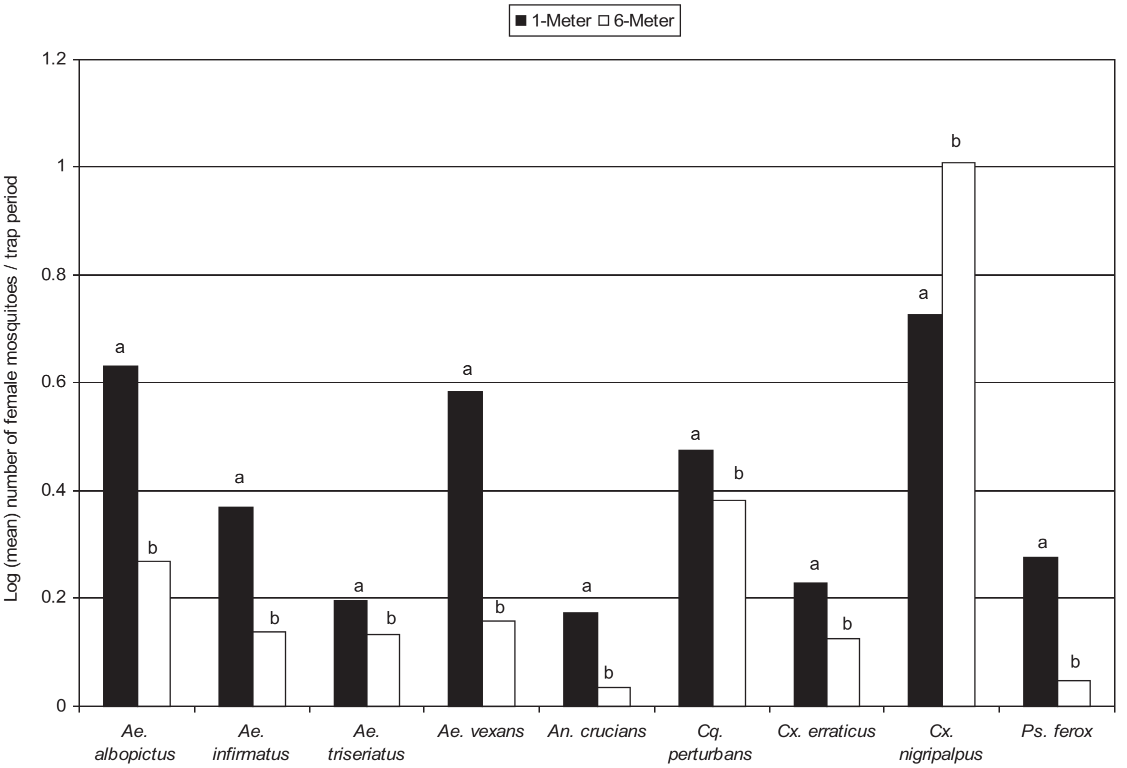

Fig. 2. Mean capture rates of the nine most commonly trapped mosquitoes at 1- and 6-m height in suburban and sylvatic locales from May to September 2007 in Gainesville, FL. Means within species with the same letter are not significantly different (REGW multiple range test). *Ae.*, *Aedes*; *An.*, *Anopheles*; *Cq.*, *Coquillettidia*; *Cx.*, *Culex*; *Ps.*, *Psorophora*.

have been less conducive to support large populations. Past studies in north-central Florida have shown *Ae. albopictus* to be more prevalent in urban areas compared with sylvatic regions (O'Meara et al. 1993). Interstate 75 is located next to San Felasco Hammock State Park. Fifty percent of the sylvatic captured *Ae. albopictus* were from the site that was closest to the Interstate. It is possible that used or damaged tires or other debris may be present along the highway–forest interface, providing suitable *Ae. albopictus* breeding sites. This site was closer to Interstate 75 and residential areas than other sylvatic sites. Residential areas tend to have numerous artificial containers, such as bird baths, rain gutters, and cans. An increase in the number of artificial breeding sites would substantially support more *Ae. albopictus* compared with natural containers, such as tree holes. Many Florida homeowners intentionally flood birdbaths and the bases of potted plants during dry periods. Furthermore, sprinkler systems commonly found in suburban areas would consistently supply other discarded containers with water, thereby providing ideal breeding sites and support active *Ae. albopictus* populations, even during times of drought.

Although *Ae. albopictus* were attracted to traps placed at 6 m, the majority (87%) were captured at 1 m. Similar results were observed in Japan where dry ice traps placed at 1 m captured significantly more *Ae. albopictus* than those placed above 1 m (Tsuda et al. 2003). It is an opportunistic feeder on a variety of hosts, including birds, and thus may serve as an encephalitis virus bridge vector to humans, particularly WN virus (Turell et al. 2001, Richards et al. 2006). The fact that 13% were captured at 6 m may have disease transmission implications and influence population control tactics because *Ae. albopictus* is susceptible to WN virus and can readily disseminate the virus once infected (Turell et al. 2001). Analysis of bloodmeals in Potosi, MI, showed that *Ae. albopictus* fed on birds 16% of the time (Savage et al. 1997). Furthermore, field-collected *Ae. albopictus* have tested positive for WN virus by the reverse transcription-polymerase chain reaction (RT-PCR) method (Cupp et al. 2007).

Studies have shown that the Mosquito Magnet Pro, Mosquito Magnet Liberty, bi-directional Fay, and ODFP traps are effective trapping tools for *Ae. albopictus* (Jensen et al. 1994, Shone et al. 2003, Hoel 2005). However, some of these traps are extremely bulky and may require heavy propane tanks for CO_2 production. Our study indicates that the BG trap may provide an effective alternative to these traps in capturing *Ae. albopictus*, regardless of locality. The BG trap by itself is lightweight, collapsible, and can be easily transported. Originally designed to capture *Ae. aegypti* and to be placed in sheltered urban environments, the BG trap performed well in less-sheltered field environments in our study. Although not significant, the BG trap caught more *Ae. albopictus* (20.0 ± 3.9) than the MM-X (14.0 ± 2.7) or ODFP (15.1 ± 3.0) traps when placed in suburban locales. Meeraus et al. (2008) found the BG trap was an effective trap compared with the CDC miniature light trap in suburban environments. Our results are similar to their study in that, whereas BG trap captures were not significantly different from other traps tested, the BG trap did capture the most *Ae. albopictus* and proved to be an effective trap for collecting *Ae. albopictus.* However, it is important to note that their study evaluated the BG trap against the CDC miniature light trap in suburban environments; in comparison, we compared the BG to commonly used diurnal traps that contain black and white colors in suburban and sylvatic environments.

Our results support other studies in north-central Florida that documented *Cx. nigripalpus* as one of the most frequently trapped mosquito species (Kline et al. 2006). *Cx. nigripalpus* has been reported to be captured equally using the CDC and MM-X traps, but our study showed that the BG trap caught significantly more *Cx. nigripalpus* compared with the MM-X and ODFP traps (Kline et al. 2006). Trap construction, suction intake, and CO_2 emission from the trap may be important factors responsible for capturing more *Cx. nigripalpus.* Compared with MM-X and ODFP traps, the BG trap has multiple outlets for CO_2 emission, houses dual chambers allowing for a push-pull mosquito intake system, and has a drain hole located at the bottom. The MM-X is known to discharge numerous short plumes of CO_2, which may increase the attraction of host-seeking mosquitoes (Cooperband and Cardé 2006). Therefore, future comparison studies using BG traps should analyze CO_2 plume structure to determine whether trap design affects CO_2 plume emission, thereby increasing trap captures.

Several studies of *Culex* species have shown similar height preferences to our results. Studies in England showed that more *Cx. pipiens* were collected in light traps placed at 5- than at 2.5- or 1-m heights (Hutchinson et al. 2007). Canopy experiments in Sweden also showed that 36% of *Cx. pipiens/torrentium* were captured between 12 and 15.5 m (Lundström et al. 1996). In New York, Darbro and Harrington (2006) captured significantly more *Cx. restuans* Theobald at 9 m than at 1.5 m. Recently, Savage et al. (2008) found chicken-baited traps placed at 7.6-m heights in urban areas of Tennessee captured a greater number of *Cx. pipiens* compared with those placed at 4.1 m. Although they did not find WN virus infection rates to be significantly different by height, those that tested positive were all from the *Cx. pipiens* complex. However, all of these locations are situated in more northern latitudes compared with Florida. Although *Cx. pipiens* feed on both mammals and birds, northern populations are known to become increasingly ornithophilic with an increase in latitude (Spielman 2001). Therefore, future studies should determine whether a change in *Cx. nigripalpus* host preference fluctuates with changes in habitat or latitude. Furthermore, trapping *Cx. nigripalpus* at specific times during the season and at heights >6 m should help elucidate host selection within habitat.

Although several mosquitoes in our study were not analyzed in detail, they are worth mentioning because of their preference for selective environments. *O. signifera* (Coquillett) was captured only in sylvatic locales; this is not surprising because their larval habitats are cryptic tree holes. In contrast, *Wyeomyia smithii* (Coquillett) and *Wy. mitchelli* (Theobald) were trapped only in suburban locales. Many of these backyards contained tank bromeliads, common breeding sites for these two species. Few studies report successful capture of *Toxorhynchites* spp. adults using mosquito traps. They have been used widely as potential biological control agents targeting *Cx. quinquefaciatus, Ae. aegypti,* and *Ae. albopictus* (Legner 1995). The numbers of *Toxorhynchites rutilus* that we captured were likely attracted to the black circular opening of the BG trap, mistaking it for a natural oviposition site such as a tree-hole (D. Kline, personal communication). Although *Toxorhynchites* spp. cannot bite and do not pose health threats, trapping adults may be a method by which to determine their presence or population estimates in a given area.

Our study showed that traps baited with host-seeking attractants are highly effective at trapping a variety of mosquitoes, including *Ae. albopictus* in sylvatic and suburban locales. The BG trap captured significantly greater numbers of *Cx. nigripalpus, Cq. perturbans, Ae. triseriatus, Ae. infirmatus,* and *Ps. ferox* compared with other traps tested. Its performance in conjunction with being collapsible and lightweight make it an attractive tool for rapid vector assessments. The BG trap is an effective surveillance device to assess populations of *Ae. albopictus* and offers an alternative to risky human landing counts, especially in areas with recent outbreaks of dengue (Effler et al. 2005) and chikungunya (Rezza et al. 2007). In addition, the placement of these baited traps at various heights identified host-seeking behaviors for a variety of mosquitoes. Future application of semiochemicals in traps, such as the BG-Mesh lure, to increase capture rates serves not only to enhance surveillance but also as a control management tool (Kline 2007).

Acknowledgments

We thank A. Rose for helpful advice regarding the BG Sentinel trap; P. Lounibos and E. Greiner for helpful suggestions regarding this study; and C. A. Stoops for an exhaustive review of this manuscript. Appreciation is also extended to the residential landowners that allowed us to conduct research on their property and the staff personnel at San Felasco Hammock Preserve State Park. We gratefully acknowledge BioGents, Regensburg, Germany, for providing lures and traps for this research. This study was supported by the University of Florida Agricultural Experiment Station federal formula funds, Project FLA-04598, received from Cooperative State Research, Education and Extension Service, U.S. Department of Agriculture.

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Received 27 October 2008; accepted 23 February 2009.