The relative attractiveness of carbon dioxide and octenol in CDC- and EVS-type light traps for sampling the mosquitoes *Aedes aegypti* (L.), *Aedes polynesiensis* Marks, and *Culex quinquefasciatus* Say in Moorea, French Polynesia

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ABSTRACT: Two dominant day-biting pests and vector species on the island of Moorea in French Polynesia are *Aedes* (*Stegomyia*) *aegypti* (L.) and *Aedes* (*Stegomyia*) *polynesiensis* Marks, major vectors of dengue viruses and *Wuchereria bancrofti*, respectively. Their surveillance is hindered by a relative lack of attraction to light traps, necessitating the undesirable use of human bait collections with the inherent risks of pathogen transmission. The effectiveness of CDC- and EVS-type light traps baited with olfactory attractants was evaluated for these two *Aedes* species and the nocturnal *Culex* (*Culex*) *quinquefasciatus* Say in three sites in urban and semi-rural environments on Moorea in October/November 2003. Firstly, four CDC-type traps with light only, light with octenol, light with carbon dioxide (dry ice), and light with octenol plus carbon dioxide were operated continuously over four days with daily rotation to compensate for position effects. Secondly, two CDC- and two EVS-type traps with carbon dioxide or carbon dioxide plus octenol were operated continuously over four days with similar rotation. Variation was found in the numbers of the three species collected at the different sites, reflecting the relative availability of their preferred larval habitats. With the CDC traps in the first trial, the addition of octenol to the light did not significantly increase the collection of any species, the addition of carbon dioxide did significantly increase collection of all three species, while the addition of octenol to the light plus carbon dioxide did not significantly increase the collections further. In the second trial, there was no significant difference in the mean number of *Ae. aegypti* or *Ae. polynesiensis* collected in either EVS or CDC traps when baited with carbon dioxide or with octenol added. For *Cx. quinquefasciatus*, the supplementation with octenol made no significant difference with EVS traps but resulted in significantly reduced collections in CDC traps. Overall, neither trap, however baited, provided large samples when compared with landing/ biting collections at human bait. Only two other species were collected, *Culex* (*Culex*) *roseni* Belkin and *Aedes* (*Aedimorphus*) *nocturnus* (Theobald), the latter being a first record for the island of Moorea and for French Polynesia. *Journal of Vector Ecology* 29 (2): 309-314. 2004.

Keyword Index: *Aedes aegypti*, *Aedes polynesiensis*, CDC and EVS traps with carbon dioxide and octenol, French Polynesia.

INTRODUCTION

The two dominant day-biting pest species on the island of Moorea in French Polynesia, *Aedes* (*Stegomyia*) *aegypti* (L.) and *Aedes* (*Stegomyia*) *polynesiensis* Marks, are the major local vectors of dengue viruses and *Wuchereria bancrofti*, respectively, while *Culex* (*Culex*) *quinquefasciatus* Say is a common night-biting pest but is generally considered a much less important vector of filariasis in the Pacific regions (Lee et al. 1987, 1989).

Surveillance of the urban and peri-urban populations of these *Aedes* mosquitoes for their abundance and infection rates is problematic. For *Ae. aegypti*, indices of larval abundance in artificial domestic containers do not adequately indicate adult abundance and the attendant risks of transmission (Tun-Lin et al. 1996). For *Ae. polynesiensis*, its appearance in artificial containers in residential environments does not indicate the more extensive colonization of natural containers such as tree-holes, palm fronds, coconuts, and crab holes and grossly underrepresents adult activity. Additionally, adult population densities of *Ae. aegypti* can be difficult to estimate as they can be relatively low compared with other species of mosquito (Reiter and Gubler 1997),
particularly species such as *Ae. polynesiensis* that can have myriad larval habitats available (Lee et al. 1987) and *Cx. quinquefasciatus* which can proliferate in high nutrient wastewater in urban areas (Lee et al. 1989). Development of accurate methods for adult surveillance of these two *Aedes* has been hindered by the relative lack of attraction of both to light traps. This problem has resulted in the use of human bait collections as the standard sampling procedure, a technique that is labor-intensive and influenced by a range of environmental, site, and collector factors, and is also undesirable because it exposes collectors to the risk of pathogen transmission (Reiter and Gubler 1997).

However, in many situations where there is a range of vector mosquito species, crepuscular and nocturnal as well as diurnal species, the facility to employ a single attractive trap is highly desirable for mosquito as well as diurnal species, the facility to employ a single of vector mosquito species, crepuscular and nocturnal undesirable because it exposes collectors to the risk of environmental, site, and collector factors, and is also undesirable because it exposes collectors to the risk of pathogen transmission (Reiter and Gubler 1997).

The comparative effectiveness of the CDC-type (as above) and the Encephalitis Virus Surveillance (EVS)-type (BioQuip Products Heavy Duty EVS CO₂ Trap Model 2801A) traps with octenol and/or carbon dioxide was investigated with four traps (two of each type) in each of the three localities. One of each type was baited with carbon dioxide (dry ice) alone and the other was baited with carbon dioxide plus octenol. The collection containers used for both traps were identical and were the solid cups supplied by BioQuip for their CDC-type trap. The traps were placed in wind-sheltered positions, operated continuously for 24 h a day for four d (with octenol continuously available and dry ice provided twice a day), and rotated between the four positions on a daily basis to compensate for position effects.

Daily collections could not be separated for logistical reasons, but this was not considered to be a critical consideration because the principal objective was simply to compare the collection of each species with the various traps and attractants at the three different locations. The numbers of each species of the three mosquitoes collected in the first trial by each CDC-type trap baited with light, octenol, and carbon dioxide across the three locations were log (x+1) transformed then compared using one-way analysis of variance (ANOVA). The numbers collected by the variously baited CDC and EVS traps in the second trial were treated similarly. For both analyses, Tukey’s pairwise multiple comparison test was used to compare means.

In parallel with the above trials, human bait landing/biting collections were undertaken for 15 min in the two h prior to sunset, in the vicinity of the traps, to provide a comparison of techniques.

**RESULTS**

In the first trial, there was great variation in the numbers of the three species collected by the CDC traps within and between the three sites (Table 1), reflecting the relative local availability of preferred larval habitats and adult production as indicated by the prior local human bait collections and larval surveys, as mentioned above. *Aedes aegypti* was the most abundant *Aedes* species at Pao Pao, while *Ae. polynesiensis* was predominant at Gump Station and Vaihara. Analysis of
these data showed that the addition of octenol to the light attraction of the CDC trap did not significantly increase the collections of any species. The addition of carbon dioxide to the light did significantly increase collections of each species at all three sites, but the supplementation of carbon dioxide with octenol did not increase collections further (Table 2).

In the second investigation, the same variation in relative abundance of the *Aedes* species at the three sites was demonstrated (Table 3). Analysis of these data showed no significant difference in mean numbers of *Ae. aegypti* and *Ae. polynesiensis* collected by either CDC or EVS traps, however they were baited. For *Cx. quinquefasciatus*, there was no significant difference in numbers collected by either trap baited with carbon dioxide alone. The addition of octenol to the carbon dioxide bait resulted in significantly reduced collections with CDC traps but this impact was not seen with the EVS traps (Table 4).

In comparison, the landing/biting collections at human bait produced relatively larger numbers of both *Aedes* species (but not *Cx. quinquefasciatus*) within the smaller collection period. For *Ae. aegypti*, there were 15 females at Pao Pao, 3 females at Gump, and 4 females at Vaihara per 15 min and for *Ae. polynesiensis* there were 4 females at Pao Pao, 17 females at Gump, and 22 females at Vaihara, per 15 min collecting time.

Two other species were recorded in the trap collections at Vaihara (Table 3), *Culex* (*Culex* roseni Belkin and *Aedes* (*Aedimorphus*) *nocturnus*, Theobald), the latter being a first record for the island of Moorea and for all of French Polynesia.

### DISCUSSION

These investigations occurred during October and November, in the latter half of the ‘so-called’ dry season, but some rain fell patchily during each month and increased in amount and frequency over the three months from September. Populations of both species increased from September through November along with the increasing rainfall and humidity (data not included).

The operation of the traps throughout the 24 h day was designed to allow the collection of mosquitoes displaying diurnal, crepuscular, and nocturnal activity. *Aedes aegypti* in Malaysia displayed its greatest biting activity in mid-morning and late afternoon (Macdonald 1956), similar to that found in Kenya (Teesdale 1955). In Trinidad, Chadee (1988) found diurnal peaks at 0600-0700 and 1700-1800 h with the morning peak being slightly greater, but in a later report (Chadee and Martinez 2000) described a trimodal pattern of landing with consistent peaks at 0700, 1100, and 1700 h that was similar to the trimodal pattern reported from Tanzania by Corbet and Smith (1974) and from Indonesia by Atmosodjono et al. (1972) which had earlier been dismissed as due to sampling error or seasonal or geographic factors. Additionally, *Ae. aegypti* is well known for extended host-seeking activity and for taking multiple blood meals in a single gonotrophic cycle (Macdonald 1956, Scott et al. 1993).

*Aedes polynesiensis* was found generally to be a daytime biter in Fiji (Rakai et al. 1974), while in American Samoa and Independent Samoa, Jachowski (1954) and Suzuki and Sone (1973), respectively, reported the species to be diurnally active with a major peak of activity in late...
afternoon and a lesser peak in the early morning, and maximum biting activity was recorded between 1500 and 1800 h in both cases. *Culex quinquefasciatus*, however, is generally accepted to be nocturnally active and typically bites after 2200 h (Lee et al. 1989), although early evening biting activity has been reported for the Pacific from Fiji (Rakai et al. 1974).

Reports of mosquito collections using these miniature light traps with various attractants have been variable with respect to relative numbers and particular species. Smith et al. (1979), in the initial comparison of the newly developed EVS trap (Rohe and Fall 1979) with the earlier CDC trap (Sudia and Chamberlain 1962), found the former better for collecting *Culex* (*Culex*) *tarsalis* Coquillett but not *Culex* (*Culex*) *erythrothorax* Dyar. Later, Ritchie and Kline (1995) showed in southeast Queensland, Australia that CDC-type traps (baited with dry ice) consistently collected greater overall numbers of mosquitoes than did EVS-type CO₂ traps, but not for all species. However, comparing collection data between studies using different traps, and from different studies using ostensibly the same traps, is problematic as even relatively similar miniature light traps such as the CDC and EVS traps differ in their component and structural details. Moreover, the EVS-type used in the present study was an advanced model, different than those used by Ritchie and Kline (1995), and had more batteries (three rather than two D-cell) driving an improved motor that collected through an enlarged (11.5 cm rather than 8 cm diameter) pipe section. The CDC-type used in the present study was the “standard” model, with a 6-volt battery and pipe diameter of 8 cm. The motors in the traps of the present study were identical, but the propeller in the CDC trap was four-bladed rather than two-bladed as in the EVS trap, and the CDC trap lamp was a substantially greater light source than that in the EVS trap.

The supplementation of carbon dioxide bait with octenol has been reported to significantly increase collections of some mosquitoes (including various aedine species), but not others (particularly *Culex* species), in various traps in various geographic regions (Takken and Kline 1989, Kline et al. 1991, Kemme et al. 1993, Kline et al. 1994).

Table 2. Mean number (± S.D.) of *Aedes aegypti*, *Aedes polynesiensis*, and *Culex quinquefasciatus* collected in CDC-type light traps and also baited with carbon dioxide (dry ice) and/or octenol (1-octen-3-ol) at Moorea, French Polynesia, October 2003.

<table>
<thead>
<tr>
<th>Species</th>
<th>LIGHT</th>
<th>LIGHT+OCT</th>
<th>LIGHT+CO₂</th>
<th>LIGHT+OCT+CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ae. aegypti</em></td>
<td>0.33±0.58 a¹</td>
<td>1.00±1.00 a</td>
<td>15.00±12.49 b</td>
<td>11.00±8.66 b</td>
</tr>
<tr>
<td><em>Ae. polynesiensis</em></td>
<td>0.33±0.58 a</td>
<td>2.33±0.58 a</td>
<td>13.33±5.51 b</td>
<td>8.00±5.29 b</td>
</tr>
<tr>
<td><em>Cx. quinquefasciatus</em></td>
<td>2.33±1.53 a</td>
<td>1.00±0.00 a</td>
<td>8.00±4.36 b</td>
<td>3.67±1.53 ab</td>
</tr>
</tbody>
</table>

¹Means followed by the same letter are not significantly different (P<0.05); Tukey’s multiple comparison test applied to log(x+1) transformed data.

Table 3. Numbers of *Aedes aegypti*, *Aedes polynesiensis*, and *Culex quinquefasciatus* collected in CDC- and EVS-type light traps baited with carbon dioxide (dry ice) and also octenol (1-octen-3-ol), over 24 h for four d, in three locations between Cooks Bay and Opunohu Bay, Moorea, French Polynesia, November 2003.

<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
<th>CO₂</th>
<th>CO₂ + octenol</th>
<th>CO₂</th>
<th>CO₂ + octenol²</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ae. aegypti</em></td>
<td>Pao Pao</td>
<td>14</td>
<td>9</td>
<td>18</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Gump Stn</td>
<td>3</td>
<td>0</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Vaihara</td>
<td>5</td>
<td>3</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td><em>Ae. polynesiensis</em></td>
<td>Pao Pao</td>
<td>6</td>
<td>0</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Gump Stn</td>
<td>26</td>
<td>4</td>
<td>19</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Vaihara</td>
<td>31</td>
<td>7</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td><em>Cx. quinquefasciatus</em></td>
<td>Pao Pao</td>
<td>15</td>
<td>2</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Gump Stn</td>
<td>11</td>
<td>2</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Vaihara</td>
<td>11</td>
<td>0</td>
<td>15</td>
<td>3</td>
</tr>
</tbody>
</table>

¹At Vaihara, *Culex (Culex) roseni* and *Aedes (Aedimorphus) nocturnus* were also captured - the latter being a new species record for Moorea and French Polynesia. ²At Vaihara, *Aedes (Aedimorphus) nocturnus* was also captured.
1994, Van Essen et al. 1994, Ritchie and Kline 1995). In a comparison of octenol and carbon dioxide attracting *Ae. aegypti* to Fay-Prince traps in Queensland, octenol was reported to significantly decrease collections (Canyon and Hii 1997). Similar results were reported recently with another *Stegomyia* mosquito, where significantly more *Aedes (Stegomyia) albopictus* (Skuse) were collected in Maryland with Fay-Prince traps baited with carbon dioxide or carbon dioxide plus octenol, when compared with unbaited or octenol-only baited traps, and octenol was found to be of no benefit (Shone et al. 2003).

However, there is no published information on the reaction of *Aedes (Stegomyia)* species in the Pacific region to CDC or EVS traps baited with carbon dioxide and/or octenol. The data reported from the present study indicate the species respond well to the use of carbon dioxide in these traps, but there appears to be no value in the use of octenol as an attractant, either alone or in conjunction with carbon dioxide. Overall, however, the numbers collected by either the CDC or EVS traps when baited with carbon dioxide were not substantial when compared with the standard technique of human bait collections. This finding was similar to those reported by Canyon and Hii (1997) who compared Fay-Prince traps with human bait collections in Queensland, and Jones et al. (2003) who found that human bait collections in Thailand were much more effective than the omni-directional Fay-Prince trap, the Centers for Disease Control Wilton trap, and the Austech International “sticky lure” in collecting *Ae. aegypti* adults for population surveillance. Schoeler et al. (2004) reported from Peru that the American Biophysics (ABC-PRO) light trap, the omni-directional Fay-Prince trap, and the CDC Wilton trap were not effective collectors of *Ae. aegypti* when compared with human landing collections and particularly with backpack-aspirator collections.

In conclusion, it would appear that human bait landing/biting collections may be required to serve as the most effective method for collecting adult *Aedes aegypti* and other *Stegomyia* species in the Pacific region for the foreseeable future.

**Acknowledgments**

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**REFERENCES CITED**


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**Table 4. Mean number (± S.D.) of *Aedes aegypti*, *Aedes polynesiensis* and *Culex quinquefasciatus* collected in CDC- and EVS-type light traps baited with carbon dioxide (dry ice) and also octenol (1-octen-3-ol) at Moorea, French Polynesia, November 2003.**

<table>
<thead>
<tr>
<th></th>
<th>CDC</th>
<th></th>
<th>EVS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO₂</td>
<td>CO₂+OCT</td>
<td>CO₂</td>
<td>CO₂+OCT</td>
</tr>
<tr>
<td><em>Ae. aegypti</em></td>
<td>7.33±5.85 a</td>
<td>4.00±4.58 a</td>
<td>11.00±6.25 a</td>
<td>5.00±5.20 a</td>
</tr>
<tr>
<td><em>Ae. polynesiensis</em></td>
<td>21±13.23 a</td>
<td>3.67±3.51 a</td>
<td>15.67±4.93 a</td>
<td>9.33±7.76 a</td>
</tr>
<tr>
<td><em>Cx. quinquefasciatus</em></td>
<td>12.33±2.31 a</td>
<td>1.33±1.15 b</td>
<td>14.00±5.56 a</td>
<td>4.00±1.73 ab</td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not significantly different (P<0.05); Tukey’s multiple comparison test applied to log(x+1) transformed data.*


