

## COMPARISON OF OCTENOL- AND BG LURE®-BAITED BIOGENTS SENTINEL TRAPS AND AN ENCEPHALITIS VIRUS SURVEILLANCE TRAP IN PORTLAND, OR

SETH R. IRISH,<sup>1,3</sup> FABRICE CHANDRE<sup>2,3</sup> AND RAPHAEL N'GUESSAN<sup>1,3</sup>

**ABSTRACT.** Two types of mosquito trap were tested near Smith Lake in Portland, Multnomah County, OR: 2 Biogents Sentinel (BGS) traps baited with carbon dioxide (CO<sub>2</sub>) and an octenol sachet or a BG Lure®, and an encephalitis virus surveillance (EVS) trap with CO<sub>2</sub> but without an odor sachet. After 6 trap-nights, the 2 BGS traps caught significantly more mosquitoes than the EVS trap. More *Culex tarsalis* and an overall greater number of species were caught in the BGS traps. A BGS trap and an EVS trap, both baited with CO<sub>2</sub> alone, were compared to investigate whether the difference was due to the attractants or the difference in trap type. The BGS trap caught more mosquitoes but the difference was not significant. The BGS trap, when baited with CO<sub>2</sub> and other lures, can be an effective mosquito sampling tool, but further research is needed to understand the importance of the attractants.

**KEY WORDS** EVS trap, Biogents Sentinel, carbon dioxide, octenol, mosquitoes

### INTRODUCTION

Mosquito sampling is an important part of any mosquito control effort. It allows for better understanding of the biology and behavior of mosquitoes, which can be useful for making better decisions in disease and mosquito control programs.

Carbon dioxide (CO<sub>2</sub>) has been used successfully in mosquito trapping. The CO<sub>2</sub> given off by animals is used by mosquitoes both in activation (takeoff and sustained flight) as well as in host location (Gillies 1980). Carbon dioxide for mosquito trapping is primarily provided as live hosts (as in human landing catches), dry ice, and tanked carbon dioxide (Service 1993).

The Centers for Disease Control and Prevention (CDC) light trap has often been used in combination with CO<sub>2</sub>, usually in the form of dry ice, to sample mosquitoes. To facilitate the use of dry ice with a CDC miniature light trap, Rohe and Fall (1979) designed the encephalitis virus surveillance (EVS) trap. This trap is widely used for mosquito surveillance in the United States.

In addition to CO<sub>2</sub>, other compounds can be added to traps to increase their efficiency. Octenol (1-octen-3-ol) is a compound present in ox odor, which is also given off in small amounts in human sweat (Clements 1999). Its attractant properties were investigated with tsetse flies (Hall et al. 1984). Takken and Kline (1989) evaluated its attractiveness to mosquitoes and found that octenol and CO<sub>2</sub> had a synergistic effect in attracting *Ochlerotatus*<sup>4</sup>

*taeniorhynchus* Wiedemann, *Anopheles* spp., and *Wyeomyia mitchellii* Theobald. Catches of *An. albimanus* Wiedemann were increased with octenol in Venezuela (Rubio-Palis 1996) as were *Oc. vigilax* Skuse catches in Australia (Van Essen et al. 1994). *Coquillettidia perturbans* Walker and *Mansonia titillans* Walker catches also increased with octenol in Florida (Kline et al. 1990). In all these studies, carbon dioxide was the primary attractant, with octenol maximizing these catches. Octenol alone was either not tested, or was not found to be as effective as CO<sub>2</sub> alone in attracting mosquitoes. In other situations, octenol was not found to increase catch size significantly (Becker et al. 1995).

In preliminary trials, catches of *Culex* mosquitoes were not significantly increased by adding octenol to traps (Takken and Kline 1989). This was believed to be due to the fact that many *Culex* spp. have the majority of their blood meals from birds, not mammals like oxen, which give off octenol. This seemed to be further confirmed as *Cx. salinarius* Coquillett, which feeds on a variety of hosts, including mammals (Murphey et al. 1967), was found to be attracted to octenol (Kline et al. 1990). However, collections of *Cx. annulirostris* Skuse and *Cx. sitiens* Wiedemann, whose host preferences include mammals, were not increased by the addition of octenol to traps (Kempe et al. 1993, Van Essen et al. 1994, Van den Hurk et al. 2006). This difference may be due to differences between species or in mammals selected by these species as hosts.

The BG-Sentinel (BGS) trap was designed by the BioGents Corporation (BioGents GmbH, Regensburg, Germany) to sample one of the main mosquito vectors of dengue, *Aedes aegypti* Linnaeus. An octenol lure sachet (AgriSense, Pontypridd, United Kingdom) can be added, as can the BG Lure® (BioGents GmbH, Regensburg, Germany, supplied by AgriSense). The BG

<sup>1</sup> London School of Hygiene and Tropical Medicine, Keppel Street, London, WC1E 7HT, United Kingdom.

<sup>2</sup> Institut de Recherche pour le Developpement (IRD/UR016), 01 BP 4414, Cotonou, Bénin.

<sup>3</sup> Centre de Recherche Entomologique de Cotonou (CREC), 06 BP 2604, Cotonou, Bénin.

<sup>4</sup> The use of the *Ochlerotatus* genus name follows the classification described by Reinert (2000).



Fig. 1. The BGS trap with dry ice container and tube.

Lure is a synthetic lure developed to mimic human odors. It consists of lactic acid, ammonia, and caproic acid on a long-lasting lure (Kröckel et al. 2006). Carbon dioxide can also be added to increase the attractiveness of the trap.

The BGS trap blows odors out of the exterior of the top of the trap while sucking in mosquitoes that approach the interior of the top of the trap. The black-and-white color scheme of the trap follows other successful *Aedes* sampling traps, such as the Fay-Prince trap (Fay 1968, Fay et al. 1970). The BGS trap has been found to be more effective than the CDC backpack aspirator in sampling *Ae. aegypti* (Maciel-de-Freitas et al. 2006, Williams et al. 2006). Recent studies have found the BGS trap to be effective in catching a variety of mosquito species belonging to *Aedes*, *Anopheles*, *Culex*, and *Culiseta* in Germany (Küpper et al. 2006, Molnar 2006, Rose et al. 2006).

The purpose of this study was to compare a BGS trap baited with octenol and CO<sub>2</sub>, a BGS trap baited with the BG Lure and CO<sub>2</sub>, and an EVS trap baited with CO<sub>2</sub> only. As the most common mosquitoes in the area are *Cx. tarsalis* Coquillett and *Cx. pipiens* Linnaeus, the efficacy of the BGS traps in catching these species was also tested.

#### MATERIALS AND METHODS

The study was carried out in north Portland (45°36'7"N, 122°43'20"W) Multnomah County,

OR, from July 19 to September 13, 2006. The site location was along a tree line south of Smith Lake. The Columbia Slough runs just south of the tree line.

The 2 BGS traps and the EVS trap were baited with CO<sub>2</sub> (1 kg dry ice for each trap). One BGS trap was baited with an octenol sachet and the other was baited with the BG Lure. Crushed dry ice was placed into plastic Gatorade bottles (Gatorade, Chicago, IL). A hole was made in the plastic bottle cap and a length of plastic tubing (interior diameter 0.95 cm) was inserted. The tubing ran from the bottle to a wire frame, which held the end of the tube 10 cm above the opening of the BGS trap (Fig. 1).

BGS traps used electric current from a nearby house. The EVS trap used batteries, which were recharged before each use.

Three trap sites were located along a tree line facing a temporary pool near Smith Lake with 20 m between each trap. The traps were rotated in a Latin square design. Over 6 trap-nights, each trap spent 2 nights in each trapping location. The traps were set each night between 5:00 and 7:00 p.m. Sunset was after 8:00 p.m. Traps were retrieved between 7:00 and 8:30 a.m. each morning. Mosquitoes were identified to species. After the 1st series of trap-nights, 8 more trapping events were performed between August 29 and September 13, with the use of 1 BGS trap and 1 EVS trap. These followed the same procedure as the 1st 6 trap-nights; however, in both traps only CO<sub>2</sub> was used. The objective was to find out if there was a significant difference between traps with similar attractants.

As the catches did not follow a normal distribution, nonparametric methods (Kruskal-Wallis test for comparing all 3 traps and Mann-Whitney *U*-tests for comparing 2 traps) were used to analyze trap catches. Total numbers of mosquitoes and numbers of important species in the traps were analyzed.

#### RESULTS

During the 1st study, 5,370 mosquitoes were caught, mainly: *Cx. tarsalis* (82.6%) and *Cx. pipiens* (7.2%), and *An. punctipennis* Say (5.7%) (Table 1). Other species caught were *Cs. incidens* Thomson, *Cs. inornata* Williston, *Cs. particeps* Adams, *An. freeborni* Aitken, *Ae. vexans* Meigen, *Oc. sticticus* Meigen, *Oc. washinoi* Lanzaro & Eldridge, and *Cq. perturbans*.

The EVS trap caught fewer total mosquitoes than both the BGS trap with octenol ( $P = 0.03$ ) and the BGS trap with the BG Lure ( $P = 0.03$ ) but the difference between the 2 BGS traps was not significant ( $P = 0.57$ ). Both BGS traps caught more *Culex* spp. than the EVS trap. There was no significant difference between the 2 BGS traps though the trap with the BG Lure caught more

Table 1. Mean catches  $\pm$  standard error (SE) of each trap baited with CO<sub>2</sub> between July 19 and August 3, 2006.<sup>1</sup>

|                               | Biogents Sentinel BG Lure®     | Biogents Sentinel octenol     | Encephalitis virus surveillance |
|-------------------------------|--------------------------------|-------------------------------|---------------------------------|
| <i>Culex tarsalis</i>         | 334.3 <sup>ab</sup> $\pm$ 70.4 | 283.3 <sup>a</sup> $\pm$ 30.8 | 121.8 <sup>b</sup> $\pm$ 33.4   |
| <i>Anopheles punctipennis</i> | 15.7 <sup>a</sup> $\pm$ 9.48   | 28.5 <sup>b</sup> $\pm$ 6.6   | 5.2 <sup>a</sup> $\pm$ 1.7      |
| All mosquitoes                | 402.7 <sup>a</sup> $\pm$ 75.9  | 333.5 <sup>a</sup> $\pm$ 34.7 | 158.8 <sup>b</sup> $\pm$ 38.6   |

<sup>1</sup> Numbers in the same row sharing a letter superscript do not differ significantly ( $P > 0.05$ ).

total mosquitoes. However, the BGS trap with octenol caught significantly fewer *Cx. pipiens* ( $P = 0.02$ ) and more *Cx. tarsalis* ( $P = 0.01$ ) than the EVS trap. The BGS trap baited with octenol caught significantly more *An. punctipennis* than the EVS trap ( $P = 0.005$ ), and more total mosquitoes than the BGS trap baited with the BG Lure, but the difference was not significant ( $P = 0.054$ ).

The BGS traps caught more mosquito species than the EVS trap. *Culiseta incidens*, *Cs. inornata*, *Cs. particeps*, *Oc. washinoi*, *Oc. sierrensis* Ludlow, and *Cq. perturbans* were caught in both BGS traps but not in the EVS trap. *Ochlerotatus sticticus* was only caught in the BGS trap baited with octenol.

During the 8 trap-nights when only CO<sub>2</sub> was used as an attractant, 1,373 mosquitoes were caught, with a majority of *Cx. pipiens* (89.9%), as opposed to the earlier trapping when *Cx. tarsalis* were more prevalent. Only 70 *Cx. tarsalis* were caught during this period. Other species caught were *Cs. incidens*, *An. freeborni*, *An. punctipennis*, and *Ae. vexans*.

The mean number caught in the BGS trap was 90.5 mosquitoes per trap-night, whereas the EVS trap caught 81.1 mosquitoes per trap-night (Table 2). Though the BGS trap caught more mosquitoes, the difference was not significant ( $P = 0.14$ ). The same number of species was caught in both BGS and EVS traps.

## DISCUSSION

Both of the BG Sentinel traps caught significantly more mosquitoes than the EVS trap. In addition to catching more total mosquitoes, the BGS traps caught more *Culex* spp. than the EVS traps. This increase in attractiveness may have been due to the volatile chemicals given off by the

lures (octenol and the BG Lure), differences in the method of CO<sub>2</sub> dispersal, or differences in the trap designs itself.

It is unlikely that the different methods of CO<sub>2</sub> dispersal would result in large differences in mosquitoes caught, considering that the same amount of dry ice (1 kg) was used in both situations, a small amount of dry ice was usually remaining each morning in both traps (indicating similar release rates), and the distances above the trap opening were the same. The only difference was the CO<sub>2</sub> came out of a tube for the BGS traps and out of small holes on the dry ice bucket for the EVS trap.

It was not expected that octenol would increase the attraction of the traps for *Cx. tarsalis* and *Cx. pipiens*. Becker et al. (1995) found that octenol did not significantly increase trap catches of *Cx. pipiens*. Burkett et al. (2001) found octenol actually decreased catches of *Cx. pipiens* in Korea. In North Carolina, Rueda et al. (2001) caught more *Cx. pipiens* in traps baited with octenol and CO<sub>2</sub> than in traps baited with CO<sub>2</sub> alone. However, these were relatively low numbers. In general, octenol does not increase attraction of *Cx. pipiens* (Kline 1994). In this study, the BGS trap baited with octenol caught the fewest number of *Cx. pipiens*; however, the BGS trap baited with octenol caught significantly more *Cx. tarsalis* than the EVS trap ( $P = 0.01$ ).

The 8 trap-nights using only CO<sub>2</sub> as an attractant did not give a significant difference in the number of mosquitoes caught by the BGS trap and the EVS trap. This may be due to the small number of trapping events. More trap-nights might have resulted in a more significant difference. To measure the influence of trap type and attractant on *Culex* mosquitoes, these factors would have to be analyzed simultaneously. Kilpatrick et al. (2006) described a late-season

Table 2. Mean catches per trap  $\pm$  standard error (SE) between August 29 and September 13, 2006. Both the encephalitis virus surveillance (EVS) trap and the Biogents Sentinel (BGS) trap were baited with CO<sub>2</sub>, but no other attractants.

|                               | BGS trap        | EVS             | <i>P</i> value of difference |
|-------------------------------|-----------------|-----------------|------------------------------|
| <i>Culex</i> spp.             | 84.5 $\pm$ 14.3 | 78.5 $\pm$ 28.0 | 0.29                         |
| <i>Anopheles punctipennis</i> | 3.25 $\pm$ 1.3  | 1.1 $\pm$ 0.4   | 0.21                         |
| All mosquitoes                | 90.5 $\pm$ 13.1 | 81.1 $\pm$ 14.3 | 0.14                         |

shift in feeding behavior from birds to mammals by *Cx. pipiens*. *Culex tarsalis* also experiences a feeding shift, with increased mammal feeding particularly in July and August (Tempelis et al. 1965). It would be interesting to investigate whether or not octenol becomes a more important attractant after these shifts.

Significantly more *An. punctipennis* were caught in the BGS trap baited with octenol than in the trap baited with the BG Lure or the EVS trap. This seems to indicate an attraction to octenol, which is consistent with its host feeding on mammals (Tempelis and Washino 1967, Tempelis 1975). Rueda et al. (2001) caught more *An. punctipennis* in CDC light traps baited with CO<sub>2</sub>, light, and octenol than traps baited with only CO<sub>2</sub> and light. However, they found CO<sub>2</sub> and light caught more *An. punctipennis* than CO<sub>2</sub> and octenol. In this study, the EVS trap had CO<sub>2</sub> and light but did not catch more than the BGS trap that was baited with CO<sub>2</sub> and octenol. This may be due to a difference in trapping efficacy between the BGS trap and the EVS trap.

Even so, the lack of difference between the 2 traps in the absence of odor attractants seems to point to the importance of these attractants. Further research is needed to determine the role of octenol and the BG Lure on the trapping of different species.

In conclusion, the BGS traps using octenol or the BG Lure were more effective in sampling most species, including *Cx. tarsalis*, than the EVS trap using CO<sub>2</sub> alone. The addition of octenol to the BGS trap appeared to decrease catches of *Cx. pipiens* but increase those of *An. punctipennis*. It appears that the BGS trap with the addition of CO<sub>2</sub> and octenol or the BG Lure is an effective tool for mosquito sampling.

#### ACKNOWLEDGMENTS

Work was conducted in Multnomah County, based at Multnomah County Vector and Nuisance Control, 5235 N. Columbia Blvd., Portland, OR 97203. Special thanks are due to James Dreiling, who provided support and the electricity for the traps throughout this study. Thanks are also due to Elaine Stewart and Metro for their understanding. Also, thanks to Multnomah County Vector and Nuisance Control for their support throughout the study. Alex Asidi, Clémence Metonnou, Abibatou Odjo, and Pélagie Boko made valuable comments on the manuscript. Owen Jones of AgriSense provided the traps and lures.

#### REFERENCES CITED

- Becker N, Zgomba M, Petric D, Ludwig M. 1995. Comparison of carbon dioxide, octenol, and a host-odour as mosquito attractants in the Upper Rhine Valley, Germany. *Med Vet Entomol* 9: 377-380.
- Burkett DA, Lee WJ, Lee KW, Kim HC, Lee HI, Lee JS, Shin EH, Wirtz RA, Cho HW, Claborn DM, Coleman RE, Klein TA. 2001. Light, carbon dioxide, and octenol-baited mosquito trap and host-seeking activity evaluations for mosquitoes in a malarious area of the Republic of Korea. *J Am Mosq Control Assoc* 17:196-205.
- Clements AN. 1999. *The biology of mosquitoes. Volume 2: sensory reception and behaviour*. New York: CABI Publishing.
- Fay RW. 1968. A trap based on visual responses of adult mosquitoes. *Mosq News* 28:1-7.
- Fay RW, Prince WH. 1970. A modified visual trap for *Aedes aegypti*. *Mosq News* 30:20-23.
- Gillies MT. 1980. The role of carbon dioxide in host-finding by mosquitoes (Diptera: Culicidae): a review. *Bull Entomol Res* 70:525-532.
- Hall DR, Beevor PS, Cork A, Nesbitt BF, Vale GA. 1984. 1-octen-3-ol. A potent olfactory stimulant and attractant for tsetse isolated from cattle odours. *Insect Sci Appl* 5:335-339.
- Kemme JA, Van Essen PHA, Ritchie SA, Kay BH. 1993. Response of mosquitoes to carbon dioxide and 1-octen-3-ol in Southeast Queensland, Australia. *J Am Mosq Control Assoc* 9:431-435.
- Kilpatrick AM, Kramer LD, Jones MJ, Marra PP, Daszak P. 2006. West Nile virus epidemics in North America are driven by shifts in mosquito feeding behavior. *PLoS Biology* [Internet] 4:e82. [accessed March 13, 2008]. Available from: <http://biology.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pbio.0040082&ct=1>.
- Kline DL. 1994. Olfactory attractants for mosquito surveillance and control: 1-octen-3-ol. *J Am Mosq Control Assoc* 10:280-287.
- Kline DL, Wood JR, Morris CD. 1990. Evaluation of 1-octen-3-ol as an attractant for *Coquillettidia perturbans*, *Mansonia* spp. and *Culex* spp. associated with phosphate mining operations. *J Am Mosq Control Assoc* 6:605-611.
- Kröckel U, Rose A, Eiras AE, Geier M. 2006. New tools for surveillance of adult yellow fever mosquitoes: comparison of trap catches with human landing rates in an urban environment. *J Am Mosq Control Assoc* 22:229-238.
- Küpper S, Schulze S, Maier WA, Kampen H. 2006. Beitrag zum Vorkommen und zur Verbreitung von Stechmücken (Diptera: Culicidae) in Nordrhein-Westfalen mit besonderer Berücksichtigung des Großraums Bonn. *Mitt Dtsch Ges Allg Angew Entomol* 15:337-344.
- Maciel-de-Freitas R, Eiras AE, Lourenço-de-Oliveira. 2006. Field evaluation of effectiveness of the BG-Sentinel, a new trap for capturing adult *Aedes aegypti* (Diptera: Culicidae). *Mem Inst Oswaldo Cruz* 101:321-325.
- Molnar T. 2006. Comparative studies of two trapping systems for mosquito surveillance in Bavaria, Germany. *Vector Ecol Newsl* 37:10-11.
- Murphey FJ, Burbutis PP, Bray DF. 1967. Bionomics of *Culex salinarius* Coquillett. II. Host acceptance and feeding by adult females of *C. salinarius* and other mosquito species. *Mosq News* 27:366-374.
- Reinert JF. 2000. New classification for the composite genus *Aedes* (Diptera: Culicidae: Aedini), elevation of

- subgenus *Ochlerotatus* to generic rank, reclassification of the other subgenera, and notes on certain subgenera and species. *J Am Mosq Control Assoc* 16:175–188.
- Rohe DL, Fall RP. 1979. A miniature battery powered CO<sub>2</sub> baited light trap for mosquito borne Encephalitis surveillance. *Bull Soc Vector Ecol* 4:24–27.
- Rose A, Kröckel U, Bergbauer R, Geier M, Eiras AE. 2006. Der BG-Sentinel, eine neuartige Stechmückenfalle für Forschung und Überwachung. *Mitt Dtsch Ges Allg Angew Entomol* 15:345–348.
- Rubio-Palis Y. 1996. Evaluation of light traps combined with carbon dioxide and 1-octen-3-ol to collect anophelines in Venezuela. *J Am Mosq Control Assoc* 12:91–96.
- Rueda LM, Harrison BA, Brown JS, Whitt PB, Harrison RL, Gardner RC. 2001. Composition and adult activity of salt-marsh mosquitoes attracted to 1-octen-3-ol, carbon dioxide, and light in Topsail Island, North Carolina. *J Am Mosq Control Assoc* 17:61–66.
- Service MW. 1993. Mosquito ecology: Field sampling methods. London: Elsevier Applied Science.
- Takken W, Kline DL. 1989. Carbon dioxide and 1-octen-3-ol as mosquito attractants. *J Am Mosq Control Assoc* 5:311–316.
- Tempelis CH. 1975. Host-feeding patterns of mosquitoes, with a review of advances in analysis of blood meals by serology. *J Med Entomol* 11:635–653.
- Tempelis CH, Reeves WC, Bellamy RE, Lofy N. 1965. A three-year study of the feeding habits *Culex tarsalis* in Kern County, California. *Am J Trop Med Hyg* 14:170–177.
- Tempelis CH, Washino RK. 1967. Host-feeding patterns of *Culex tarsalis* in the Sacramento Valley California, with notes on other species. *J Med Entomol* 4:315–318.
- Van Den Hurk AF, Montgomery BL, Zborowski Beebe NW, Cooper RD, Ritchie SA. 2006. Does octen-3-ol enhance trap collections of Japan Encephalitis virus mosquito vectors in North Australia? *J Am Mosq Control Assoc* 22:15–21.
- Van Essen PHA, Kemme JA, Ritchie SA, Kay E. 1994. Differential responses of *Aedes* and *Culex* mosquitoes to octenol or light in combination with carbon dioxide in Queensland, Australia. *Med Entomol* 8:63–67.
- Williams CR, Long SA, Russell RC, Ritchie SA. 2006. Field efficacy of the BG-Sentinel compared with CDC backpack aspirators and CO<sub>2</sub>-baited EVS traps for collection of adult *Aedes aegypti* in Cairns, Queensland, Australia. *J Am Mosq Control Assoc* 22:296–300.