Journal of the American Mosquito Control Association, 15(3):276–282, 1999
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COMPARISON OF TWO AMERICAN BIOPHYSICS MOSQUITO TRAPS: THE PROFESSIONAL AND A NEW COUNTERFLOW GEOMETRY TRAP

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ABSTRACT. Large cage and field studies were conducted to compare the efficacy of 2 American Biophysics Corporation mosquito traps, the standard professional (PRO) trap and a new counterflow geometry (CFG) trap. The PRO trap utilizes conventional downdraft technology and the CFG trap uses a patent-pending technology. In large cage studies, similarly baited CFG traps captured approximately 1.7 times as many laboratory-reared *Aedes taeniorhynchus* as the PRO trap. The CFG trap baited with CO_2 + octenol resulted in significantly reduced landing counts compared to all other treatments; mean landing count was reduced from 233.8 (12.99/min), when no trap was present, to 24.7 (1.37/min). In field studies against natural populations of woodland species, the CFG trap captured 7.8 times more mosquitoes than the PRO trap overall, and approximately 11 times more *Anopheles crucians, Anopheles quadrimaculatus,* and *Culex erraticus.*

KEY WORDS Mosquitoes, traps, counterflow technology, downdraft, updraft, woodland species

INTRODUCTION

Use of traps to control mosquitoes has received renewed interest because control with chemical insecticides is becoming less desirable. Reasons for this include increased costs associated with the registration process, increased resistance by mosquitoes to registered chemicals, and an increased recognition of the need to protect the environment against chemical pollution. The recent successes achieved with baited traps and targets for tsetse control in Zimbabwe have provided the impetus for the evaluation of this approach for other biting Diptera, including mosquitoes (Vale 1993, Day and Sjogren 1994, Torr 1994).

Unfortunately, very little is known about the impact of mosquito traps on population dynamics. In fact, until the past few years, only variations of 2 basic types of mosquito traps, the Centers for Disease Control (CDC) miniature light trap (Sudia and Chamberlain 1962) and the standard New Jersey (NJ) light trap (Mulhern 1942), routinely have been used for surveillance by mosquito abatement programs in the United States. Variations of these 2 trap types have been used in light-trap designs (Service 1993), which differ widely in size, weight, electric power requirements, and type and intensity of light. Both trap types share certain basic features, such as the use in each of a motor-driven, rotary fan to move attracted insects down into a holding container suspended beneath the trap. Air moves through the downdraft trap in a vertical path. However, with this arrangement, beetles, moths, and many other nontarget insects, attracted by the light, are easily drawn into the container where they are killed. In recent years, some mosquito control agencies have used these traps with or without light and supplemented with carbon dioxide (CO_2) and or 1-octen-3-ol (octenol).

Further modification to the CDC trap to reduce the capture of nontarget insects has been to reverse the direction of air flow. This change lifts attracted insects into a container above the trap, thus discriminating in favor of mosquitoes and similar lightweight specimens. This modification, known as an updraft trap, has been demonstrated to increase the capture of some mosquito species (Rupp and Jobbins 1969, Wilton and Fay 1972).

Few published data exist on the efficacy of these traps. Based on studies conducted in a large outdoor screened enclosure with mosquitoes of known age and quantity (Kline, unpublished data), it was determined that an unbaited (except for either a 25- or 40-W incandescent lamp) NJ trap captured approximately 1% of the released mosquitoes. A CDC trap using only a CM47 lamp captured <1% of the released mosquitoes. The addition of CO_2 (200 ml/min) increased the capture rate to 16.5%, and the subsequent addition of CO_2 + octenol (4 mg/h) increased the capture to 26%. Based on these findings, it was concluded that more efficient trapping technology, including the development of better trap designs and new attractants, was needed to make trap-based mosquito control a viable option.

Several members of the private sector have recently become interested in developing improved trapping technology for mosquito control. American Biophysics Corporation (ABC) (East Greenwich, RI) has been very active in the development of new mosquito traps. This paper reports the results of large outdoor cage and field studies conducted to compare the efficacy of their standard professional (PRO) trap with a new trap, known as the counterflow geometry (CFG) trap, which is designed with their patent-pending counterflow technology.

MATERIALS AND METHODS

Traps: The ABC PRO trap (Fig. 1) is a relatively new trap similar to the CDC trap in design and

Fig. 1. American Biophysics Corporation (ABC) professional (PRO) trap with CO_2 tank and metering equipment.

function. Like the CDC trap, the PRO trap has 3 major components: lid, body, and net. Additionally, a power source is required. In the PRO trap, each of the 3 major components has undergone modifications compared to the CDC trap, with many options available. These modifications and options were reviewed by McNelly (1995) in a study comparing operational suitability of the 2 trap types. In the present studies, the standard configuration of the PRO trap was used, which consisted of a rugged lid, formed from acrylonitrile–butadiene–styrene (ABS) plastic, with a strap and hanger that screws onto the top of the trap. The lid also has a female luer fitting for receiving CO_2 from a tank through a regulator set, and subsequently releasing it through 3 holes around the outside body of the trap. Basically, this lid mimics the form and function of the CDC trap's aluminum "pizza pan," that is, to shelter the trap body and collection net attached below from rainfall. The body is formed from a white polyvinyl chloride (PVC) cylinder. It contains the motor, fan, and electronics module. The direct current (DC) motor with a multibladed fan is rated for 1,500 h of operation. The trap is powered by a 6-V, 10-ampere-hour rechargeable gel-cell battery, which is capable of operating the trap continuously for up to 72 h when fully charged. The trap's electronics are found on a circuit board in the top of the trap body. These include a reverse-polarity diode that guards the trap against a reversed hookup to the battery, and a photo sensor for optional automatic operation. With automatic operation, both the fan and light turn on at dusk and the light shuts off at dawn. The photo sensor can be deactivated by moving a few shunts found on the circuit board. This feature enables the trap to be turned on and off manually via battery hookup, which is the way the trap was operated in the present studies. Wire connections were made to the circuit board with screw-style attachments. The circuit board and all wire connections were seated in the top of the trap body. The 6-V battery attached to the trap via a 1.98-m (6.5-ft) cord. The net, ABC's NET1, featured a removable bottom tray for ease of catch removal, a shelter for preventing catch desiccation, and an opening closed by hook-and-loop tape for aspirating live samples. In these studies, the traps were suspended from a pole so that the top opening was approximately 1.6 m (5.25 ft) above ground level.

Counterflow geometry trap: This is a new trap design, which is not yet commercially available. It utilizes a novel, patent-pending, counterflow concept. The trap (Fig. 2) is constructed from a clear PVC pretzel container (ca. 11.4 liter), modified by removing the bottom and adding a mounting flange and a 10.16-cm (4-in.)-diameter × 17.78-cm (7-in.) length of PVC thin-wall pipe. Inside the 10.16-cm pipe, a 5.08-cm (2-in.)-diameter × 30.48-cm (12-in.) length of PVC pipe was mounted concentric with, and extended 7.62 cm (3 in.) beyond the end of the 10.16-cm pipe. The lid of the jar was modified by attaching an 80-mm fan (Delta model DFB0812H, made by Delta Products Corp., Morrisville, NC) above and a suitable filter structure below the lid. The 80-mm fan was positioned to blow air out of the pretzel jar and thus induce a supply draft between the 10.16-cm pipe and the 5.08-cm pipe. Inside the filter structure, a 40-mm fan (Delta model DFB0412M) was mounted in a manner to seal the 5.08-cm tube from the container and provide an airflow out of the container in a direction opposite the flow created by the 80-mm fan. In the side of the 5.08-cm pipe, a small tube (0.32-cm [0.125-in.] inner diameter) was attached to provide an entrance port for CO_2 to enrich the exit plume from the 40-mm fan. Above the 80-mm fan, a small lid was attached to prevent rain damage to the fan and to the mosquito collection.

In operation, both the fans were energized with 12-V DC and provide a counterflow in the trap entrance geometry (Fig. 3). A CO_2-enriched plume exits vertically down from the center pipe. Insects were able to approach the trap by navigating the

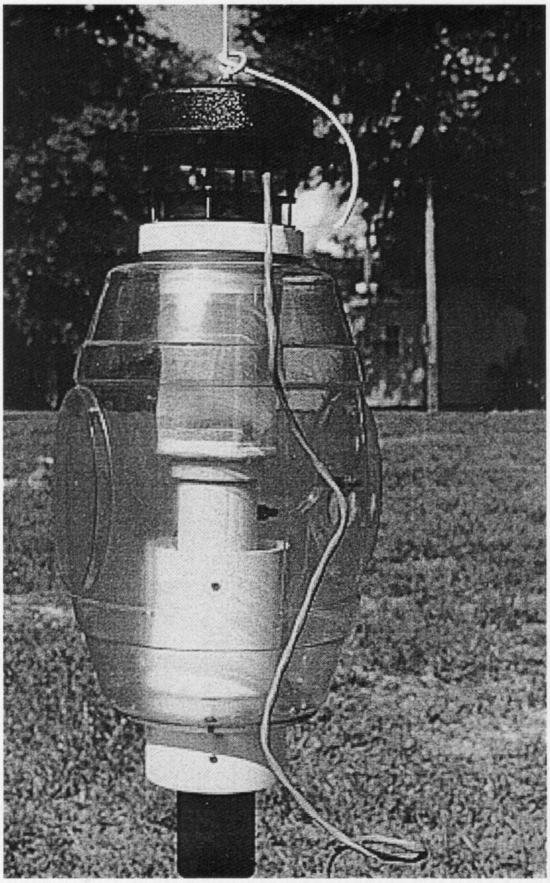

Fig. 2. Counterflow geometry (CFG) trap.

attractant plume until they reached the vicinity of the trap entrance. The upflow provided by the 80-mm fan causes any insect in the vicinity of the trap entrance with a flight speed less than approximately 3.5 m/sec to be entrained in the upflow and forced into the trap interior. Because many insects have a tendency to reverse direction by flying up rather than down, their avoidance behavior tended to bring them closer to the trap entrance. The CFG trap was hung from a pole so that the bottom of the attractant plume was approximately 50 cm (19.69 in.) above ground level.

Attractants: Carbon dioxide was supplied from 9-kg (20-lb) compressed gas cylinders. A flow rate of 500 ml/min was used for all trap–bait combinations. Control of CO_2 flow rate was achieved with ABC's FLOWSET1 pressure regulator with an output fixed at 15 psig, a 10-μm line filter, a 500-ml/min flow control orifice, and quick-connect luer fittings. American Biophysics Corporation's OCT1 Slow Release 1-Octen-3-ol Packets were used to supply the octenol. Each packet contained a crushable glass vial containing 1 ml of octenol. The glass vial was encased in a plastic woven mesh and enclosed in a 2nd filter paper, and further enclosed in an outer low-density polyethylene (LDPE) pouch. The glass vial was crushed to release the octenol. The odor of octenol permeated the inner pouch and was detectable about 1 h after crushing at room temperature (21°C) . After that time, the packet released octenol at a rate of approximately 0.5 mg/h until the supply was exhausted (ca. 2 months). The release rate will increase with increased temperature and be reduced at lower temperatures. For these studies, a fresh package was used each trap night.

Outdoor screened cage studies: Comparisons were made in a large outdoor screened enclosure (9.2 m wide × 18.3 m long × 4.9 m high on the sides and 6.1 m high at the peak) where 1,000 3- to 4-day-old laboratory-reared *Aedes taeniorhynchus* Wiedemann were released each night 90 min before sunset, 250 in each corner. Each trap type was operated with either no bait, 500 ml/min CO_2 only, or 500 ml/min CO_2 + 1 package of ABC octenol for a minimum of 3 randomly selected nights. Traps were retrieved approximately 90 min after sunrise and the number of mosquitoes caught in the traps was determined.

The impact that these various trap–bait combinations had on landing rate counts within the cage was also determined. Landing counts were taken along a transect extending from the southwest (SW) to northeast (NE) corners of the large cage. Three sampling stations were established along this transect: the 2 corners (SW and NE) and the midpoint of the transect, which was where the treatment traps were located. For 6 min, at each station mosquitoes were aspirated into a collection tube with a modified portable vacuum cleaner as they attempted to land on a human host. A different collection tube was used at each station. Collection tubes were placed into a freezer to kill the mosquitoes for counting. For this determination in addition to the test nights for the trap–bait combinations, 9 nights were utilized in the cage to obtain a baseline when no trap–bait combinations were used. Landing counts were made approximately 90 min after sunrise on the morning after mosquitoes were released into the 4 corners of the cage.

Data were transformed by $\log(n + 1)$ and subjected to GLM (for analysis of variance) and Means/REGWQ (for means comparison) procedures (SAS Institute 1985). Unless otherwise stated, $P \leq 0.05$.

Field studies: Field studies were conducted in Alachua County, Florida, in a wooded area adjacent to bay and cypress swamps. Two trap stations approximately 50 m apart were established for this study. Treatments, consisting of 1 CFG and 1 PRO trap, each baited with 500 ml/min CO_2, were alternated each night between the 2 trap stations for 12 nights between April 9 and May 7, 1997.

Species with a total collection ≥ 12 specimens were included in data sets for statistical analyses. The procedure UNIVARIATE, which performs the

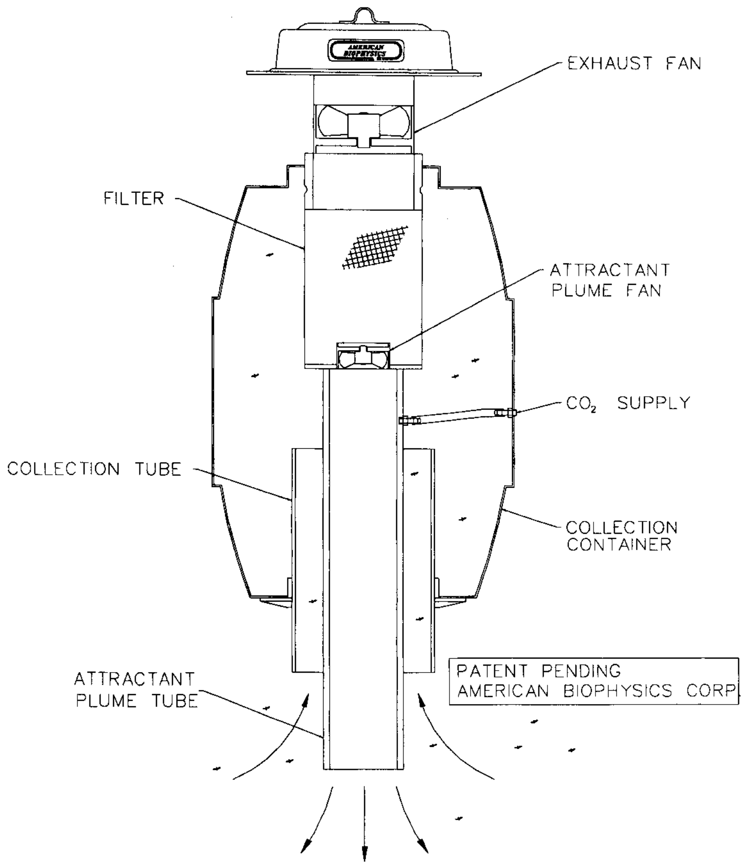

Fig. 3. Illustration of the counterflow geometry (CFG) trap and counterflow movement of air through the trap.

paired-difference *t*-test (SAS Institute 1985), was used to analyze log(n + 1)-transformed data to determine whether the mean difference between the 2 treatments is different from zero at $P \leq 0.05$.

RESULTS

Cage studies

In the large cage, significantly greater ($P \leq 0.05$) numbers of *Ae. taeniorhynchus* were captured with the CFG traps compared to the PRO traps when both were baited with either CO_2 alone or with CO_2 + octenol (Table 1). The addition of a package of ABC's slow-release octenol increased trap collections, but not significantly, for both the CFG (17.27%) and PRO (22.4%) traps. Neither trap type caught any mosquitoes when tested without a chemical attractant.

The presence of baited traps decreased landing counts (Table 1), but were significant ($P \leq 0.05$) only when traps were baited with both CO_2 and octenol. The CFG trap baited with CO_2 + octenol resulted in significantly reduced landing counts compared to all other treatments as the mean landing count was reduced from 233.8 (12.99/min) to 24.7 (1.37/min) when no trap was present.

Field studies

Eighteen species of mosquitoes were collected during 12 nights of trapping. In descending order of abundance, they were *Anopheles crucians* Wiedemann, *Coquillettidia perturbans* (Walker), *Aedes canadensis* (Theobald), *Culex salinarius* Coquillett, *Culex erraticus* (Dyar and Knab), *Aedes infirmatus* Dyar and Knab, *Anopheles quadrimaculatus* Say, *Aedes vexans* (Meigen), *Aedes atlanticus* Dyar and Knab, *Anopheles punctipennis* (Say), *Psorophora columbiae* (Dyar and Knab), *Aedes triseriatus* (Say), *Aedes dupreei* (Coquillett), *Orthopodomyia signifera* (Coquillett), *Aedes mitchellae* (Dyar), *Psorphora ciliata* (Fabricius), *Aedes aegypti* (Linnaeus), and *Culiseta melanura* (Coquillett). *Aedes aegypti, Ae. dupreei,* and *Cs. melanura* were absent from the PRO trap collections; *Ae. mitchellae, Or. signifera,* and *Ps. ciliata* were absent from the CFG trap collections.

A total of 5,220 mosquitoes was collected, 4,627 and 593 for the CFG and PRO traps, respectively.

Table 1. Efficacy of various trap–bait combinations and their impact on landing rate (aspirator) counts of laboratory-reared female *Aedes taeniorhynchus* in a large outdoor screened enclosure.

Trap–bait	No. nights tested	Mean[1] no. mosquitoes collected (standard error)					
		Trap			Aspirator		
None	9	—			233.8	(7.8)	A
CFG[2]—no bait	3	0.0		C	223.0	(31.8)	A
PRO[3]—no bait	3	0.0		C	219.3	(9.3)	A
PRO + CO_2	6	271.8	(23.3)	B	166.2	(27.9)	A
CFG + CO_2	9	481.0	(40.8)	A	112.9	(14.5)	A
PRO + CO_2 + Oct	3	332.7	(29.7)	A	65.7	(3.3)	AB
CFG + CO_2 + Oct	7	563.3	(37.7)	A	24.7	(6.1)	C

[1] Means followed by the same letter are not significantly different (0.05 significance level) as determined by SAS Institute REGWQ (SAS Institute 1985).
[2] CFG, counterflow geometry trap.
[3] PRO, professional trap.

Total mosquito collection was significantly greater ($P < 0.05$) for the CFG trap (Table 2). Only 8 species were considered abundant enough to be included in statistical evaluations (Table 2). Collections for 7 of these species were significantly greater with the CFG trap. *Aedes infirmatus* was collected in slightly, but not significantly, greater numbers in the PRO trap.

DISCUSSION

Previous traps utilized an upflow design with varying degrees of success. Rupp and Jobbins (1969) 1st published an account of a trap in which the fan was mounted above the light source to provide an updraft of air to draw mosquitoes into the trap. Unfortunately, although they presented a photograph of the trap together with some constructional details, they gave neither a complete description, nor any worthwhile results concerning trap efficiency. Wilton and Fay (1972) developed and evaluated an ultraviolet (UV) light updraft trap. In their design, air was drawn upward and expelled at right angles through a collecting cage. In laboratory experiments, this modified trap caught significantly more (42–78%) *Anopheles albimanus* Weidemann and *Anopheles stephensi* Liston than a conventional trap having a downwind displacement of air (up to 28%). From observations on the movements of mosquitoes dusted with fluorescent powders, Wilton and Fay (1972) concluded that mosquitoes encountering an air stream produced by a light-trap attempt to evade by vigorous flight activity. With conventional traps, a forward thrust as well as an upward flight movement is involved. This tends to help mosquitoes escape capture, but increases their likelihood of capture in updraft traps. The UV updraft light traps of Wilton and Fay (1972) have proved useful in collecting *An. albimanus* in Haiti (Taylor et al. 1975) and in El Salvador (Wilton 1975a).

Wilton (1975b) described a UV light trap consisting of a 4-W blacklight fluorescent tube (peak radiation about 3,650 Å) operated from a 12-V car battery through an inverter, and a 6-V DC motor with a 2-bladed fan connected through a 75-Ω resistor to the same battery. The trap is constructed so that it can operate as a downdraft trap with the light above, or by inverting it as an updraft trap with the light below. In field trials in El Salvador,

Table 2. Relative capture of natural populations of woodland mosquitoes by American Biophysics Corporation professional (PRO) and counterflow geometry (CFG) traps baited with CO_2 (500 ml/min) and octenol during 12 nights between April 9 and May 7, 1997.

Species	Mean no. mosquitoes captured (standard error)		$\|T\|$[1]	Pr > $\|T\|$[2]
	CFG	PRO		
All species	385.6 (73.5)	49.4 (10.9)	4.76	0.0006
Anopheles crucians	292.4 (62.8)	23.8 (5.9)	4.42	0.0010
Coquillettidia perturbans	64.4 (14.1)	18.3 (5.3)	3.79	0.0030
Aedes canadensis	10.3 (3.7)	2.3 (0.8)	2.36	0.0380
Culex salinarius	9.2 (2.4)	1.5 (0.5)	3.13	0.0095
Culex erraticus	3.5 (1.1)	0.3 (0.2)	3.01	0.0119
Anopheles quadrimaculatus	2.2 (0.6)	0.2 (0.1)	3.39	0.0061
Aedes infirmatus	1.3 (0.4)	1.7 (0.7)	0.41	0.6920
Aedes vexans	1.1 (0.6)	0.1 (0.1)	1.97	0.0745

[1] *t*-Test statistic for paired-difference *t*-test determined by SAS Institute Proc Univariate (SAS Institute 1985).
[2] Pr > |T| values less than 0.05 indicate the average difference is significantly different from zero.

the trap caught 2.4 times the numbers of female *An. albimanus* when used in the updraft configuration as compared with the downdraft configuration.

In Haiti, Sexton et al. (1986) compared a CDC trap, a modified updraft UV light trap, and human bait collections for sampling *An. albimanus.* Their updraft trap consisted of the cylindrical plastic body of a CDC trap with the motor and fan mounted upside down to create an updraft. A 15.2-cm-long 4-W blacklight fluorescent strip (peak emission near 3,650 Å) was positioned horizontally across the bottom of the cylindrical body. The fluorescent tube operated through an inverter ballast from a 12-V motorcycle battery with a power of 7 or 6 A, while a 75-Ω resistor allowed the 6-V motor to run from the same 12-V battery. The updraft UV trap caught the most *An. albimanus* (7,682), followed by biting collections (2,207) and CDC light traps (1,343). Grothaus and Jackson (1972) also designed an updraft trap and found the updraft principle seemed to enhance mosquito collections while simultaneously reducing the catch of unwanted large insects.

In the present study, the superiority of the CFG trap for collecting more mosquitoes over the conventional PRO trap is evident. The major difference between the counterflow geometry used in the CFG trap and the updraft principle used in previous devices is the capability of the counterflow device to provide an attractant plume that has a high concentration of attractant at the trap entrance. The other upflow devices either used light only as an attractant or, when using CO_2, had the attractant blown away from the trap entrance in the plume of the suction fan. The counterflow principle utilizes the hypothesis that mosquitoes orient toward a potential host by navigating the top of CO_2-enriched plumes formed through exhaled breath and skin emanations of potential hosts. The device also makes use of an additional hypothesis that mosquitoes will avoid flight through plumes of increasing CO_2 concentration gradients. Thus, background levels of CO_2 concentration are not as important as the plume gradient. Data supporting this hypothesis can be found in Grant et al. (1995).

Our findings are supported by recent studies conducted in East Africa (Mboera et al. 1999), in which 4 types of mosquito-sampling tools (CDC light-on trap, CDC light-off trap, CFG trap, and electric nets) were compared at 2 sites. Each sampling tool was baited with CO_2 discharged from a pressurized gas cylinder at the rate of 300 ml/min. Results showed that CO_2-baited CFG traps and the electric nets were superior to both CDC light-off and CDC light-on traps in collecting host-seeking *Anopheles gambiae* Giles and *Culex quinquefasciatus* Say when set in an outdoor environment. For the other mosquito species, the CFG trap collected significantly larger numbers of *Anopheles coustani* Laveran and *Aedes circumluteolus* Theobald than the CDC light-off trap. In further studies conducted in Tanzania, Mboera (personal communication) concluded that CFG traps baited with oviposition attractants can effectively be used to sample gravid *Cx. quinquefasciatus.*

In view of these results, further studies are planned to compare the CFG trap with other traditional updraft traps for further evaluation of the counterflow principle under cage and field conditions. Such studies are needed to confirm the general superiority of traps based on counterflow technology.

ACKNOWLEDGMENTS

I want to thank ABC, East Greenwich, RI, for supplying the traps for these studies. I want to thank Bruce Wigton, President of ABC, for his engineering persistence that led to the development of the counterflow trap, his suggestions during the course of this study, and for reviewing this manuscript. I want to thank Mark Miller, formerly of ABC, for his role in developing the counterflow technology and his stimulating conversations on mosquito trapping in general. I would also like to acknowledge my biological technician, H. T. McKeithen, for performing the statistical analyses of these data.

REFERENCES CITED

Day, J. F. and R. D. Sjogren. 1994. Vector control by removal trapping. Am. J. Trop. Med. Hyg. 50(Suppl.): 126–133.

Grant, A. J., B. Wigton, J. Aghajanian and R. J. O'Connell. 1995. Electrophysiological responses of receptor neurons in mosquito maxillary palp sensilla to carbon dioxide. J. Comp. Physiol. A 177:389–396.

Grothaus, R. H. and S. C. Jackson. 1972. A new bottom-draft light trap for mosquito studies. Mosq. News 32: 632–635.

Mboera, L. E. G., B. G. J. Knols, M. A. Braks and W. Takken. 1999. Comparison of carbon dioxide baited trapping systems for sampling outdoor mosquito populations in Tanzania. Med. Vet. Entomol. (in press).

McNelly, J. R. 1995. An introduction to the ABC trap. Proc. Annu. Mtg. N.J. Mosq. Control Assoc. 82:47–52.

Mulhern, T. D. 1942. New Jersey mechanical trap for mosquito surveys. New Jersey Agric. Exp. Stn. Circ. 421. NJ.

Rupp, H. R. and D. M. Jobbins. 1969. Equipment for mosquito surveys: two recent developments. Proc. 56th Annu. Mtg. N.J. Mosq. Exterm. Assoc., pp. 183–188.

SAS Institute. 1985. SAS procedure guide, version 6 ed. SAS Institute, Cary, NC.

Service, M. W. 1993. Mosquito ecology: field sampling methods, 2nd ed. Elsevier Applied Science, New York.

Sexton, J. D., J. H. Hobbs, Y. St. Jean and J. R. Jacques. 1986. Comparison of an experimental updraft ultraviolet light trap with the CDC miniature light trap and biting collections in sampling for *Anopheles albimanus* in Haiti. J. Am. Mosq. Control Assoc. 2:168–173.

Sudia, W. D. and R. W. Chamberlain. 1962. Battery-operated light trap, an improved model. Mosq. News 22: 126–129.

Taylor, R. T., M. Solis, D. B. Weathers and J. W. Taylor. 1975. A prospective study of the effects of ultralow

(ULV) aerial applications of malathion on epidemic *Plasmodium falciparum* malaria. II. Entomologic and operational aspects. Am. J. Trop. Med. Hyg. 24:188–193.

Torr, S. J. 1994. The tsetse (Diptera: Glossinidae) story: implications for mosquitoes. J. Am. Mosq. Control Assoc. 10:258–265.

Vale, G. A. 1993. Development of baits for tsetse flies (Diptera: Glossinidae) in Zimbabwe. J. Med. Entomol. 30:831–842.

Wilton, D. P. 1975a. Mosquito collections in El Salvador with ultra-violet and CDC miniature light traps with and without dry ice. Mosq. News 35:522–525.

Wilton, D. P. 1975b. Field evaluation of three types of light traps for collection of *Anopheles albimanus* Wiedemann (Diptera: Culicidae). J. Med. Entomol. 12:382–386.

Wilton, D. P. and R. W. Fay. 1972. Air flow direction and velocity in light trap design. Entomol. Exp. Appl. 15: 377–386.