EVALUATION OF 1-OCTEN-3-OL AS AN ATTRACTANT FOR *COQUILLETTIDIA PERTURBANS, MANSONIA* SPP. AND *CULEX* SPP. ASSOCIATED WITH PHOSPHATE MINING OPERATIONS[1]

D. L. KLINE, J. R. WOOD[2] AND C. D. MORRIS[3]

U. S. Department of Agriculture, Agricultural Research Service, Insects Affecting Man and Animals Research Laboratory, P. O. Box 14565, Gainesville, FL 32604

ABSTRACT. Field studies were conducted in phosphate mined areas of Polk County, FL, to determine the responses of mosquitoes produced as a result of mining operations to octenol and carbon dioxide. There was a highly significant response of all species except *Culex erraticus* and *Anopheles quadrimaculatus* to CO_2. Also, a significant negative octenol response was shown for *An. quadrimaculatus. Coquillettidia perturbans, Mansonia titillans* and *Cx. salinarius* had an increased response to octenol relative to no attractant. There was a slightly negative interactive effect between octenol and 500 cc/min CO_2 for *Anopheles* spp. and *Culex* (*Melanoconion*) spp. Both *Cq. perturbans* and *Ma. titillans* showed a significant synergistic enhancement in catch with octenol supplemented CO_2 when compared with CO_2 alone. However, their response to CO_2 was not significantly different at 2 release rates (200 and 500 cc/min). There was a slightly greater than additive effect for the combination of octenol and CO_2 for *Cx. nigripalpus*.

INTRODUCTION

Phosphate mines in Polk County, FL, provide the majority of habitat found in the county for species of the genera *Mansonia* and *Coquillettidia*, the aquatic stages of which require attachment to roots of aquatic plants as part of their life cycle. An estimated 240 ha (600 acres) of *Pistia stratiodes* Linn. (water lettuce) found in mined areas produce essentially all the *Mansonia dyari* Belkin, Heinemann and Page, and an estimated 1920 ha (4,800 acres) of *Eichhornia crassipes* (Mart) Solms. (water hyacinth) produce, primarily, *Ma. titillans* (Walker), a ravenous man-biting species. Mined areas also produce *Coquillettidia perturbans* Walker in greater numbers than in unmined areas due to the extensive areas of cattails found in mined areas (Slaff and Haefner 1985a). Phosphate mined areas also produce large numbers of *Culex nigripalpus* Theobald, the primary vector of St. Louis encephalitis virus, and *Cx. salinarius* Coq. (Slaff and Haefner 1985b). Carbon dioxide (CO_2) is commonly used in the routine surveillance of these species to increase adult collections. The source of CO_2 is usually either dry ice or metered from cylinders as a gas. The latter technique allows the flow rate to be controlled.

During a series of recent field tests, 1-octen-3-ol (octenol) alone was shown to be effective as an attractant for *Aedes taeniorhynchus* Wied. (Takken and Kline 1989; Kline et al. 1990, 1991). The combination of CO_2 and octenol was a significantly more powerful attractant than either chemical alone for this species.

The objectives of the studies reported herein were to determine whether octenol alone could attract a sufficient number of any of the mosquito species associated with phosphate mining operations to be useful as an alternative attractant to CO_2 in routine surveillance, and/or if there was a synergistic effect between CO_2 and octenol for any of these species which might be exploited in any innovative control strategy.

MATERIALS AND METHODS

Field studies were conducted during fall 1987 and spring 1988, with each study consisting of a 4-consecutive-day trapping trial. The spring study also included 11 paired tests. Results of each trial are discussed separately because attractant combinations and mosquito species composition differed during each trial.

Four-day trials: Fall 1987, spring 1988: Fall and spring 4-day trials were conducted at the Lakeland Wetlands, a tertiary effluent disposal and treatment site managed by the Wastewater Operations Division of the City of Lakeland, Polk County, FL. The 660 ha (1,650 acre) site once served as a phosphate clay settling area and contains 7 cells or ponds totaling 560 ha (1,400 acres) of prime mosquito breeding habitat. Major upland vegetative types included willow, oak and pine, and aquatic vegetation included water hyacinth, pennywort, duckweed, water lettuce and cattail. The major mosquito species produced by these permanent aquatic

---

[1] Mention of a commercial or proprietary product in this paper does not constitute an endorsement of this product by the United States Department of Agriculture.

[2] Department of Entomology and Nematology, University of Florida, Gainesville, FL 32611.

[3] Polk County Environmental Services. Current address: Florida Medical Entomology Laboratory, IFAS-University of Florida, Vero Beach, FL 32962.

habitats include *An. crucians* Wied., *An. quadrimaculatus* Say, *Cq. perturbans*, *Cx. nigripalpus*, *Cx. salinarius*, *Cx. erraticus* Dyar and Knab, *Ma. dyari* and *Ma. titillans*.

Both trials were initiated by establishing the trap locations as discrete sites ca. 100 m apart along an access road located between wastewater cell numbers 2 and 3. Battery operated CDC traps (without light) were installed at each trap location.

Both fall and spring studies consisted of testing treatments (attractants) within a 4 day × 4 location Latin square type design (Cochran and Cox 1957). In both studies the treatments were randomly assigned but not replicated between the fixed locations. The treatment combinations used during the fall study included 500 cc/min CO_2, 500 cc/min CO_2 + octenol, octenol, and no bait. The treatments were relocated according to their randomly assigned day-location combinations on a 24 h schedule. The treatment combinations used during the spring study included 200 cc/min CO_2, 500 cc/min CO_2, 500 cc/min CO_2 + octenol, and octenol. A no-bait trap was alternated between 2 sites established ca. 100 m beyond locations 1 and 4 and served as a control, but was not part of the 4 × 4 Latin square design. During the spring study an additional feature was included to see if daily activity patterns of any mosquito species affected the response to any of the attractant combinations. The trap day was divided into 2 sampling periods by collecting the contents twice daily: an a.m. period (2200–0900 h EST) and a p.m. period (1800–2200 h EST). Treatments were relocated daily but remained the same for both sampling periods on a given day.

Carbon dioxide gas was metered from a 9 kg (20 lb) compressed gas cylinder at the prescribed flow rate using a pressure regulator and compact flow meter (Gilmont Instruments, Inc., Great Neck, NY) and was delivered to its release point ca. 5 cm from the trap entrance through polyethylene tubing.

Octenol was released from microreaction vials (5 ml, Supelco, Inc., Bellefonte, PA) via a wick (Dills® 15 cm pipe cleaner) protruding through a Teflon® coated neoprene septum (Supelco, Inc., Bellefonte, PA). The wick was doubled over and arranged so that ca. 2 cm protruded above the septum. Release rates were calculated to be 41.1 ± 3.0 mg/h. Each trap day the octenol level was adjusted to 4 ml and the vial inverted for several seconds to assure complete wick saturation. Vials were affixed near the trap entrance and when used in combination with CO_2, they were affixed adjacent to the CO_2 release point.

All specimens collected during the fall 1987 study were counted and identified to species except for those of the genera *Culex* and *Mansonia*. *Culex* specimens were identified to subgenus (*Culex* or *Melanoconion*). Mosquito surveillance information provided by Polk County Environmental Services (PCES) indicated *Mansonia* spp. composition ratios for the Lakeland Wetlands during the trial to be ca. 1:4 *Ma. dyari* to *Ma. titillans*, respectively. *Culex* (*Culex*) species composition during the trial period was reported to be 100% *Culex nigripalpus* and *Cx.* (*Melanoconion*) spp. composition was determined to be 100% *Cx. erraticus*.

During the spring 4-day trial, all mosquitoes were counted and identified to species except for those of the genus *Mansonia*. Between 25 and 50 individual *Mansonia* were identified to species from each collection, and this revealed that *Ma. dyari* was virtually absent from the sample population (2 specimens recorded from ca. 400 identified).

All trap counts were transformed to log (n + 1) and the transformed data were then analyzed with Statistical Analysis System (SAS) PROC GLM (SAS Institute 1985) analysis of variance to determine the effect of day, location and treatment on the number of mosquitoes of each species recovered. Means comparisons were performed on transformed data with SAS PROC MEANS/DUNCAN (SAS Institute 1985) but are reported in tables in the original scale.

Paired tests: Spring studies also included 11 paired tests conducted on 4 separate occasions between March 30 and May 19, 1988, near the International Mining Corporation (IMC) slime ponds immediately south of the city of Bartow. The testing schedule included 3 trap nights (March 30–31, May 17–18 and May 18–19) with 3 paired comparisons and 1 trap night (May 16–17) with 2 paired comparisons. On all occasions treatment pairs included using battery operated CDC traps (without light) baited with 2.25 kg (5 lb) dry ice or 2.25 kg dry ice supplemented with octenol. Dry ice was placed in cloth bags and hung from trap poles. Octenol was released using the same procedure described for the 4-day trials. Paired traps were set up ca. 30 m apart and separated from the next paired grouping by ca. 60 m.

Total counts were made for all collections. However, only 100 specimens, randomly selected, were identified to species from each trap collection. On the average, dry ice only trap collections consisted of 94.2% *Cx. salinarius* whereas the octenol supplemented collections consisted of 91.2% *Cx. salinarius*. These composition ratios were used to transform the total count data so that the analysis could be conducted on not only the total number of mosquitoes responding to each treatment but also on the respective number of responding *Cx. salinarius*. A comparison of means was done using paired difference analysis in order to eliminate any extraneous variance existing from pair to pair due to location or trap day.

RESULTS

Four-day trial: Fall 1987: A total of 41,114 female mosquitoes were trapped during the fall 4-day trial. Additionally, 176 male *Mansonia* spp. were trapped but were excluded from the analysis. Their collection trends were similar to female *Mansonia*. *Mansonia* spp. (91%) not only dominated the entire collection but were unsurpassed in each individual collection. No attempt was made to identify the *Mansonia* to species. However, mosquito surveillance records for the Lakeland Wetlands during late September provided by PCES Mosquito Control Division showed that *Ma. titillans* outnumbered *Ma. dyari* 4:1 (C. D. Morris, unpublished data). Smaller numbers of *Cx. nigripalpus* (4.2%) and *Cq. perturbans* (3.2%) were recovered along with very low numbers of *An. crucians* (1.1%), *An. quadrimaculatus* (0.1%) and *Cx. erraticus* (0.6%).

Table 1 presents the results of the SAS PROC GLM analyses and shows the attained probability values from partial F-tests of the main effects of day, location and bait on catch variability. Using a 95% confidence level, average daily mosquito catches for all species combined were not significantly different ($P > 0.05$) for the 4 trial days. However, significant differences in daily catches were reported for *An. crucians, Cx. nigripalpus* and *Mansonia* spp. *Culex nigripalpus* and *An. crucians* were more prevalent in traps during days 2 and 4, respectively, whereas *Mansonia* spp. was caught in significantly greater numbers during the first 2 days of the trial. Average mosquito catches for all species combined for each trap location also were not different ($P > 0.05$). However, a fraction of the variability in catches of *Cx. erraticus* (16%) and *Mansonia* spp. (7%) were attributable to differences in trap location. Both were collected in lower numbers at location 4.

Table 1. Significance levels of log (n + 1) obtained from main effects model (partial regression, General Linear Model Procedure (SAS Institute 1985)), for Polk Co., FL, fall 1987 field studies.

Species	Day	Location	Treatment
Anopheles crucians	0.03*	1.0	0.0003**
Anopheles quadrimaculatus	0.3	0.2	0.003**
Coquillettidia perturbans	0.3	0.4	0.002**
Culex nigripalpus	0.01*	0.14	0.0005**
Culex erraticus	0.13	0.08	0.004**
Mansonia spp.	0.03*	0.08	0.0005**
Total mosquitoes	0.11	0.12	0.0002**

* Significant at $P \leq 0.05$.
** Significant at $P \leq 0.01$.

There were highly significant differences among treatments for all groups of mosquitoes. These differences accounted for ca. 90% (R-statistic) of total catch variability and ranged from 68% for *Cx. erraticus* to 88% for *An. crucians*. Overall, the octenol supplemented CO_2 treatment caught ca. 3 times more mosquitoes than the CO_2-alone treatment (Table 2). However, because of extreme variation in the daily catches the means comparison procedure was unable to resolve any differences between them ($P > 0.05$). Significantly fewer mosquitoes were caught with octenol alone than with either CO_2 alone or octenol supplemented CO_2. However, ca. 5 times more were trapped with octenol than without bait.

A synergistic effect of the octenol supplemented CO_2 treatment is evidenced by the greater than additive effect produced by the responses of CO_2 or octenol alone for *Cq. perturbans* and *Mansonia* spp. (Table 2). A 7.7-fold increase relative to the additive effect is observed for *Cq. perturbans* whereas a 2.6-fold increase is shown for *Mansonia* spp. Whereas the octenol supplemented CO_2 treatments resulted in a slight increase in response by *Cx.*

Table 2. Mean catch ± standard error (raw data) per trap day[1] for different treatments of odor baited CDC traps, Polk Co., FL, September 29–October 2, 1987.

	Attractant			
Species	None	Octenol	500 cc/min CO_2	Octenol + 500 cc/min CO_2
Anopheles crucians	0.3 ± 0.3 B	1.3 ± 0.9 B	58.5 ± 24.0 A	53.5 ± 26.1 A
An. quadrimaculatus	0.0 ± 0.0 C	0.0 ± 0.0 C	4.0 ± 0.9 A	1.5 ± 0.5 B
Coquillettidia perturbans	1.3 ± 1.0 C	7.3 ± 5.4 C	31.3 ± 8.5 B	297.0 ± 177.2 A
Culex nigripalpus	10.3 ± 7.6 B	12.7 ± 2.4 B	187.5 ± 102.0 A	225.0 ± 74.1 A
Cx. erraticus	1.3 ± 0.8 B	4.0 ± 0.6 B	32.5 ± 15.4 A	22.3 ± 7.3 A
Mansonia spp.	44.5 ± 31.4 C	255.7 ± 53.9 B	2,343.0 ± 919.5 A	6,754.0 ± 3,129.6 A
Total mosquitoes	57.5 ± 39.0 C	281.0 ± 50.5 B	2,656.0 ± 1,010.4 A	7,353.5 ± 3,117.5 A

[1] $n = 4$ days; means in the same row followed by the same letter are not significantly different ($P > 0.05$); Duncan's multiple range test (SAS Institute 1985) applied to log (n + 1) transformed data.

nigripalpus, there was a decreased response by *An. crucians*, *An. quadrimaculatus* and *Cx. erraticus*.

Four-day trial: Spring 1988: A total of 39,122 female mosquitoes were captured during the spring 4-day trial. *Coquillettidia perturbans* (38.9%) and *Ma. titillans* (41.9%) dominated both the entire and each individual collection. Intermediate numbers of *Cx. salinarius* (13.2%) and *An. crucians* (5.3%) were captured along with very low numbers of *An. quadrimaculatus* (0.5%) and *Cx. erraticus* (0.04%). Males of *Ma. titillans* (56) and *Cq. perturbans* (4) were collected but excluded from the analysis.

Similar treatment response trends were shown during both trap periods for each of the 6 species even though tabulated treatment means comparisons differ slightly. Larger catches of all species were made during the a.m. period, which produced more variable results, larger fiducial limits and, hence, more conservative means comparisons results.

Average daily catches were significantly different ($P < 0.05$) for 3 species (Table 3). Day 3 produced greater numbers of *An. crucians* and *Ma. titillians* during both trapping periods and greater numbers of *Cq. perturbans* during the a.m. period. Additionally, a significantly greater number of both species of *Anopheles* were caught at locations 1 and 3. Otherwise, location differences were not significant except for *Cx. salinarius* in the p.m. sampling period. Treatment response was significantly different for all species during both trap periods except for *Cx. erraticus* and *An. quadrimaculatus* in the p.m. Only 17 specimens of this species were recovered during the trial, and their recovery patterns were inadequately explained by day, location or treatment effects.

Table 3. Significance levels of log (n + 1) obtained from main effects model (partial regression, General Linear Model Procedure (SAS Institute 1985)), for Polk Co., FL, spring 1988 field studies.

Species	Day	Location	Treatment
Anopheles crucians			
(PM)	0.01**	0.08	0.05*
(AM)	0.08	0.02*	0.0001**
Total	0.004**	0.05*	0.0001**
An. quadrimaculatus			
(PM)	0.2	0.08	0.1
(AM)	0.2	0.01	0.001**
Total	0.5	0.01	0.0023**
Coquillettidia perturbans			
(PM)	0.2	0.2	0.0001**
(AM)	0.04*	0.3	0.0002**
Total	0.03*	0.14	0.0001**
Culex erraticus			
(PM)	0.4	0.3	0.3
(AM)	0.09	0.1	0.4
Total	0.1	0.3	0.6
Cx. salinarius			
(PM)	0.2	0.005**	0.0001**
(AM)	0.4	0.7	0.003**
Total	0.15	0.1	0.0001**
Mansonia titillans			
(PM)	0.02*	0.8	0.01**
(AM)	0.0008**	0.6	0.0001**
Total	0.003**	0.8	0.0008**
Total mosquitoes			
(PM)	0.03	0.14	0.0016**
(AM)	0.05	0.05	0.0001**
Total	0.01	0.05	0.0001**

* Significant at $P \leq 0.05$.
** Significant at $P \leq 0.01$.

Table 4 shows the results of treatment means comparisons. No significant differences in the total number of mosquitoes responding to either the octenol supplemented 500 cc/min CO_2 or the 500 cc/min CO_2 treatment was shown even though a respective 3.4:1 recovery ratio existed. Response to both CO_2 release rates was similar. Also, even though octenol recovered ca. 5 times fewer mosquitoes than the 200 cc/min CO_2 treatment, its overall performance was significantly better (12.2:1) than the control.

Octenol supplemented CO_2 did not significantly enhance the capture of either *Anopheles* spp. In fact, *An. crucians* showed similar responses to both levels of CO_2 and the octenol supplemented CO_2. *Anopheles quadrimaculatus* exhibited a significant antagonist effect shown by an 8-fold decrease in the number recovered with the octenol supplemented CO_2 vs. the CO_2 alone. Also, both *Anopheles* spp. showed no significant enhancement in catch with octenol as compared with the control. Trap catches of *Cx. salinarius* were not significantly enhanced with octenol supplemented CO_2 or with the higher rate of CO_2. However, octenol alone did surpass the control by a factor of 6. Both *Cq. perturbans* (4:1) and *Ma. titillans* (5:1) showed a significant enhancement in catch with octenol supplemented CO_2 when compared with CO_2 alone. However, their response to CO_2 was not significantly different at the 2 release rates. Both species also showed a significant response to octenol alone by a 5- and 31-fold respective increase over the control.

Paired tests: The 11 paired tests yielded 260,680 female mosquitoes. Octenol supplemented dry ice produced greater numbers in 8 of the 11 and overall accounted for 67% (14,857 ± 2,739) of the actual total number of mosquitoes and 62% (13,550 ± 2,498) of the projected total number of *Cx. salinarius* collected, respectively. Paired difference analysis showed that the treatment combination yielded greater, though not significant, numbers of both total

Table 4. Mean catch ± standard error (raw data) per trap period[1] for different treatments of odor baited CDC traps, Polk Co., FL, May 2–6, 1988.

	Attractant				
Species	None	Octenol	200 cc/min CO_2	500 cc/min CO_2	Octenol + 500 cc/min CO_2
Anopheles crucians					
(PM)	0.0 ± 0.0 C	0.5 ± 0.5 BC	19.5 ± 18.8 AB	10.8 ± 6.2 A	2.0 ± 1.4 ABC
(AM)	0.8 ± 0.8 B	1.5 ± 0.5 B	170.0 ± 51.5 A	134.5 ± 45.6 A	183.0 ± 76.2 A
Combined	0.8 ± 0.8 B	2.0 ± 1.0 B	189.5 ± 66.9 A	145.3 ± 47.6 A	185.0 ± 75.8 A
An. quadrimaculatus					
(PM)	0.0 ± 0.0 A	0.0 ± 0.0 A	4.3 ± 4.3 A	1.8 ± 0.9 A	0.0 ± 0.0 A
(AM)	0.0 ± 0.0 C	0.0 ± 0.0 C	11.3 ± 6.5 AB	30.0 ± 21.4 A	4.0 ± 2.8 BC
Combined	0.0 ± 0.0 C	0.0 ± 0.0 C	15.5 ± 7.3 A	31.8 ± 22.1 A	4.0 ± 2.8 B
Coquillettidia perturbans					
(PM)	0.0 ± 0.0 D	6.8 ± 2.2 C	168.0 ± 133.8 B	211.3 ± 52.9 AB	523.3 ± 181.2 A
(AM)	9.0 ± 8.3 D	39.0 ± 28.9 C	335.3 ± 162.6 B	450.5 ± 232.5 B	2,065.3 ± 319.1 A
Combined	9.0 ± 8.3 D	45.8 ± 30.5 C	503.3 ± 294.2 B	661.8 ± 283.6 B	2,588.5 ± 475.4 A
Culex erraticus					
(PM)	0.0 ± 0.0 A	0.0 ± 0.0 A	0.0 ± 0.0 A	0.3 ± 0.3 A	0.0 ± 0.0 A
(AM)	0.0 ± 0.0 A	0.3 ± 0.3 A	1.0 ± 0.7 A	0.8 ± 0.8 A	2.0 ± 1.2 A
Combined	0.0 ± 0.0 A	0.3 ± 0.3 A	1.0 ± 0.7 A	1.0 ± 1.0 A	2.0 ± 1.2 A
Cx. salinarius					
(PM)	0.0 ± 0.0 D	14.0 ± 4.7 C	36.8 ± 10.3 B	74.0 ± 19.6 A	75.3 ± 14.2 A
(AM)	8.0 ± 4.1 C	35.0 ± 10.3 B	222.8 ± 11.9 A	344.0 ± 57.3 A	483.0 ± 122.2 A
Combined	8.0 ± 4.1 D	49.0 ± 15.0 C	259.5 ± 16.8 B	418.0 ± 73.4 AB	558.3 ± 122.2 A
Mansonia titillans					
(PM)	0.0 ± 0.0 C	41.3 ± 15.9 B	477.8 ± 370.1 A	254.0 ± 57.0 A	505.5 ± 342.1 A
(AM)	6.5 ± 2.1 D	158.8 ± 79.5 C	150.3 ± 43.2 BC	293.0 ± 73.8 B	2,214.5 ± 856.5 A
Combined	6.5 ± 2.1 D	200.0 ± 93.5 C	628.0 ± 408.3 B	547.0 ± 108.2 B	2,720.0 ± 1,098.6 A
Total mosquitoes					
(PM)	0.0 ± 0.0 C	62.5 ± 14.0 B	706.3 ± 527.8 A	552.0 ± 84.6 A	1,106.0 ± 424.7 A
(AM)	24.3 ± 14.1 D	234.5 ± 100.6 C	890.5 ± 260.0 B	1,252.8 ± 292.8 AB	4,951.8 ± 1,093.5 A
Combined	24.3 ± 14.1 D	297.0 ± 112.5 C	1,596.8 ± 775.1 B	1,804.8 ± 346.7 AB	6,057.8 ± 1,490.8 A

[1] $n = 4$ days; means in the same row followed by the same letter are not significantly different ($P > 0.05$); Duncan's multiple range test (SAS Institute 1985) applied to log $(n + 1)$ transformed data.

mosquitoes ($P = 0.07$) and projected numbers of *Cx. salinarius* ($P = 0.08$).

DISCUSSION

These data demonstrate the ability of octenol alone and in combination with CO_2 to attract *Cq. perturbans* and *Ma. titillans*. The responses of these species are similar to those obtained with *Ae. taeniorhynchus* (Takken and Kline 1989; Kline et al. 1990, 1991). The response of these 2 species suggests that octenol might be a substitute for CO_2 for routine surveillance. This needs further investigation during the course of an entire season so that the effects of chronological and physiological age of these species to their responses to octenol might be determined. The synergistic effect of octenol and CO_2 also shows promise for use in a removal trapping program. Phosphate mined pits often are discrete enough units that this concept could be practically tested for these species.

These data are of particular interest because of the response of *Cx. salinarius*. In other studies (Kline et al. 1990, 1991) *Culex* spp. generally did not respond to octenol alone. It appears that *Cx. salinarius* is an exception to this trend. *Culex* spp. generally prefer birds, but Murphey et al. (1967) and Crans (1964) presented data that suggested that *Cx. salinarius* fed indiscriminately on mammals and birds. In our fall study *Cx. nigripalpus* also responded slightly to octenol alone. This may be due to the seasonal host preference shift in this species. Edman and Taylor (1968) reported a seasonal shift in *Cx. nigripalpus*—with birds the preferred host in winter and spring, and mammals in early summer. Octenol has been reported by several investigators as a mammalian emanation (Hall et al. 1984, Raymer et al. 1985), but to date it has not been reported in ornithophilic emanations.

Also of special interest was the response of the anopheline species. In previous studies with octenol (Takken and Kline 1989, Kline et al. 1990, 1991), *An. atropos* Dyar and Knab, *An. crucians* and *An. quadrimaculatus* had, at best, only a slightly increased response to octenol alone relative to no bait, but a synergistic increase to the combination of octenol and CO_2. In this study both anopheline species appear to have a slightly negative response to this combination in the fall study. In the spring *An. crucians* responded according to our trend, but *An. quadrimaculatus* continued to show a negative response. This raises the question of what effect chronological and/or physiological age may have on mosquito response to octenol. Another concern is the problem of species complexes that are common among anophelines. Both *An. crucians* and *An. quadrimaculatus* consist of species complexes (Narang and Seawright 1990).

Collectively, these data indicate both the promise and the pitfalls that exist in our current state of knowledge of mosquito attractants. The promise is that there are compounds like CO_2 and octenol that can be tested in innovative strategies for mosquito control. These compounds along with others, such as acetone and phenols that have been used successfully to trap out tsetse populations in East Africa (Vale et al. 1988), need further evaluation for a wide variety of mosquito species. The pitfall is that there is much that needs to be learned about chemical communication among mosquitoes before this technique becomes practical. Why do some species respond and not others? Is it due to different chemical compounds, different combinations of the same compounds, different concentrations of the same compounds or to differences in the morphological arrangement of sensory structures on different species? What role does chronological and physiological age structure play? What problems do species complexes impose? We hope to answer these and other questions on the way to achieving our ultimate goal: i.e., the development of a trap or target baited with artificial odor powerful enough to act as a substitute for man and/or his domesticated animals before the mosquitoes can find these hosts. Today, tsetse are being caught routinely throughout East Africa with the use of odor baited traps, where the bait consists of cow urine or a mixture of kairomones that have been proven to be present in animal emanations (Bursell et al. 1988). Tomorrow, given the same dedicated effort that has gone into the success of the tsetse program, chemical attractants other than CO_2 can be used in routine surveillance and innovative mosquito management programs.

ACKNOWLEDGMENTS

This study was supported in part by research grants LCNA7 and LCNP3, Office of Entomology, Department of Health and Rehabilitative Services, Jacksonville, FL.

REFERENCES CITED

Bursell, E., A. J. E. Gough, P. S. Beevor, A. Cork, D. R. Hall and G. A. Vale. 1988. Identification of components of cattle urine attractive to tsetse flies, *Glossina* spp. (Diptera: Glossinidae). Bull. Entomol. Res. 78:281–291.

Cochran, W. G. and G. M. Cox. 1957. Experimental designs. John Wiley and Sons, Inc., New York, NY.

Crans, W. J. 1964. Continued host preference studies with New Jersey mosquitoes. Proc. N.J. Mosq. Exterm. Assoc. 51:50–58.

Edman, J. D. and D. J. Taylor. 1968. *Culex nigripalpus*: seasonal shift in the bird-mammal feeding ratio in a mosquito vector of human encephalitis. Science

161:67–68.

Hall, D. R., P. S. Beevor, A. Cork, B. F. Nesbitt and G. A. Vale. 1984. 1-Octen-3-ol: a potent olfactory stimulant and attractant for tsetse isolated from cattle odors. Insect Sci. Applic. 5:335–339.

Kline, D. L., W. Takken, J. R. Wood and D. A. Carlson. 1990. Field studies on the potential of butanone, carbon dioxide, honey extract, 1-octen-3-ol, lactic acid and phenols as attractants for mosquitoes. Med. Vet. Entomol. 4:383–391.

Kline, D. L., J. R. Wood and J. A. Cornell. 1991. Implications of the interactive effects of 1-octen-3-ol and carbon dioxide on mosquito surveillance and control. J. Med. Entomol. 28: (In press).

Murphey, F. J., P. P. Burbutis and D. F. Bray. 1967. Bionomics of *Culex salinarius* Coquillett. II. Host acceptance and feeding by adult females of *C. salinarius* and other mosquito species. Mosq. News 27:366–376.

Narang, S. K. and J. A. Seawright. 1990. Genetic differentiation among members of species complexes in anopheline mosquitoes (Diptera: Culicidae). *In:* R. C. Sobti (ed.), The eukaryotic chromosome-structural and functional aspects (in press).

Raymer, J., D. Wiesler, M. Novotny, C. Asa, U. S. Seal and L. D. Mech. 1985. Chemical investigations of wolf (*Canis lupus*) anal-sac secretion in relation to breeding season. J. Chem. Ecol. 11:593–608.

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

Slaff, M. and J. D. Haefner. 1985a. Seasonal and spatial distribution of *Mansonia dyari, Mansonia titillans*, and *Coquillettidia perturbans* (Diptera: Culicidae) in the central Florida, USA, phosphate region. J. Med. Entomol. 22:624–629.

Slaff, M. and J. D. Haefner. 1985b. The impact of phosphate mining on *Culex nigripalpus* and *Culex salinarius* (Diptera: Culicidae) populations in central Florida. Fla. Entomol. 68:444–450.

Takken, W. and D. L. Kline. 1989. Carbon dioxide and 1-octen-3-ol as mosquito attractants. J. Am. Mosq. Control Assoc. 5:311–316.

Vale, G. A., D. F. Lovemore, S. Flint and G. F. Cockbill. 1988. Odour-baited targets to control tsetse flies, *Glossina* spp. (Diptera: Glossinidae), in Zimbabwe. Bull. Entomol. Res. 78:31–49.