EVALUATION OF ULV NALED APPLIED SIMULTANEOUSLY AGAINST CAGED ADULT *AEDES TAENIORHYNCHUS* AND *CULICOIDES FURENS*[1]

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ABSTRACT. Two experiments were conducted to test application of ULV naled against adult *Aedes taeniorhynchus* and *Culicoides furens* exposed simultaneously in cages hung on poles at selected heights and distances from the spray source. ULV spray was released at 0.14 oz active ingredient/acre, droplet size 13.5 μm mmd. In both experiments, insecticide largely carried over the first poles. The greatest mortality occurred at the second pole position, 18.3 and 25.7 m, respectively, from the spray origin, and diminished progressively with increasing distance. Cages at the highest elevation (183 cm) showed the greatest mortality, while those near the ground (15 cm) were substantially less affected. Regression analysis showed that 70% control or better was attained up to a distance (beyond a line 10 m from the release point) of 23 m in the case of *Ae. taeniorhynchus* and 18 m in the case of *C. furens*. ULV naled, applied as described, was not particularly effective for control of *Ae. taeniorhynchus* and *C. furens*, and was poor for insects exposed in low vegetation.

INTRODUCTION

Giglioli et al. (1980) tested the effect of aerially applied ultra low volume (ULV) Sumithion (fenitrothion) for control of *Culicoides* (predominantly *C. furens* (Poey)) in Grand Cayman. Excellent control, better than 99%, was achieved with a dosage of 191.5 gm/ha (2.7 oz/acre) active ingredient. Similarly, Haile et al. (1984) obtained essentially the same level of control of *C. hollensis* (Melander and Brues) after two consecutive (1 day apart) serial applications of naled (Dibrom 14®) at 28.4 gm/acre (1 oz/acre). In Florida, ULV naled applied from vehicle-mounted equipment is used by many mosquito control districts predominantly as a measure against mosquitoes, but also with some anticipated effect in controlling *Culicoides*. Despite the widespread application of this method, no attempt has been made to evaluate the effect of such treatments on biting midge populations. Accordingly, we report here the results of two experiments to test the control effect of ULV naled applied against *Culicoides furens* and *Aedes taeniorhynchus* (Wiedemann) exposed simultaneously. These experiments are complementary to an earlier test to assess the effect of thermal fog naled against *C. furens* (Linley et al. 1987).

MATERIALS AND METHODS

Wild caught female *C. furens* were collected by aspiration from a site on Hutchinson Island, Florida, as previously described (Linley et al. 1987). The *Ae. taeniorhynchus* were obtained from a laboratory colony (Lake Charles strain) obtained from the USDA Insects Affecting Man and Animals Research Laboratory in Gainesville, Florida.

The insects were exposed during test in cages consisting of two compartments, a screen exposure chamber and a closed post-exposure chamber, separated by a sliding barrier. The cage used for the *Culicoides* is described fully by Linley et al. (1987) and one somewhat larger, but otherwise similar in basic design, was used for *Aedes*. Both experiments were conducted at Sarasota, Florida, in an open meadow devoid of bushes or trees and covered predominantly by grass. Grass stems were fairly dense to a height of 16–20 cm (6–8 in) above ground but relatively sparse above this height, with the tallest stems reaching to about 45 cm (18 in).

Cages were hung from hooks attached at heights of 15, 91 and 183 cm (6, 36, 72 in) to wood poles erected in pairs along two parallel lines oriented in the direction of the prevailing wind and perpendicular to the line of spray release (see Linley et al. 1987). In the two experiments, the nearest two poles were respectively 6 and 9.1 m (20, 30 ft) from the line of spray release; the two lines of poles were 6 m apart (both experiments), and pairs of poles were respectively 12.2 and 16.8 m (40, 55 ft) apart. Poles were set further apart in the second experiment in an attempt to obtain more complete coverage of the zone within which the insecticide showed some effect. Two control cages (for both *C. furens* and *Ae. taeniorhynchus*) in each experiment were hung at 91 and 183 cm on a pole set about 1 km from the treatment area, sufficient to assure no exposure to chemical.

Test insects were transferred to the cages under CO_2 anesthesia in the early morning, just prior to being transported to the field site. From

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15–20 *Ae. taeniorhynchus* and 10–40 *C. furens*, respectively, were placed in each cage. The *Culicoides* could not be counted into cages as they recover extremely rapidly from CO_2 anesthesia (<20 sec). After cages had been set out at the test site, the ULV naled treatment was applied at approximately sunrise + 1 hr. Application was made with vehicle-mounted Leco Model HD equipment, nozzle angle 45°, at 1.5 m (5 ft) elevation, dispensing 3.7 oz/km (6 oz/mile) 85% active ingredient naled (droplet size 13.5 μm mmd). Cages were left in place for 15 min after application, then insects were transferred to the post-exposure chambers and the cages returned to the laboratory. Mortality was subsequently recorded at 1, 6 and 24 h posttreatment. Conditions during the two experiments were generally very favorable, with fairly constant wind speeds (determined with a hand-held anemometer) of about 2.4 km/hr (1.5 miles/hr) in the first experiment and 6.4 km/hr (4 miles/hr) in the second.

RESULTS

Control mortalities showed no difference related to cage height and the counts were therefore combined. On this basis, at 24 hr after treatment, mortalities for *Ae. taeniorhynchus* and *C. furens* in the two experiments were 0 and 10.7%, and 4.3 and 2.1%, respectively. Where appropriate, Abbott's formula was applied to the data prior to further analysis.

Results from the two pole lines in both experiments were similar and the data for each experiment were combined. Since it is useful to have access to exact mortality figures, conventional tabulations are given in Table 1 (Exp. 1) and Table 2 (Exp. 2). However, the effects of treatment in relation to time, distance from the release point and cage elevation, are more comprehensible from isometric plots (Figs. 1,2). Survival rather than mortality percentages were plotted in these figures because, as argued previously (Linley et al. 1987), concern is more with proportions of insects surviving than with those eliminated.

The overall pattern of effect in the two experiments was similar (Figs. 1,2). Mortality generally tended to be higher in Experiment 1, in which wind speed was lower (2.4 km/hr) than under the somewhat higher wind speed (6.4 km/hr) prevailing during Experiment 2 (Tables 1,2). Mortality in most instances was higher in the caged groups of *Ae. taeniorhynchus* than among the *C. furens* (Tables 1,2; Figs. 1,2), possibly because insecticide was not able to pass as easily through the finer mesh necessary to confine *Culicoides*. Only in Experiment 1, and then only in two groups of *Ae. taeniorhynchus* at higher cage elevations, were all the insects dead after 24 hr (Table 1).

It was obvious from the survival plots, especially in the 24 hr time blocks (Figs. 1,2), that both mosquitoes and midges survived considerably better in cages in the first pair of poles than on the second. Evidently, and especially with higher wind speed (Exp. 2), much of the insecticide carried over the first poles and consequently produced only moderate effect. The highest mortalities for both species were, as expected, in cages of 183 cm (Tables 1,2), but even then, the highest mortality (*Ae. taeniorhynchus*, Exp. 2) was only 51.2%. At the distance of the second pair of poles in the two experiments (18.3 and 25.7 m, respectively), control was substantially better as is especially obvious from the survival data (Figs. 1,2). More than 70% of the *Ae. taeniorhynchus* were dead after 24 hr at all elevations in Experiment 1 (Table 1), and more than 75% at the two highest

Table 1. Percent mortality of adult female *Aedes taeniorhynchus* (not italicized) and *Culicoides furens* (italicized) exposed to ULV naled (Exp. 1).

Distance (m) from release point	Time (hr) after treatment								
	1			6			24		
	Height (cm)			Height (cm)			Height (cm)		
	15	91	183	15	91	183	15	91	183
6.1	40.0	25.0	41.0	42.5	40.0	48.7	45.0	45.0	48.7
	14.0	*20.9*	*18.2*	*26.2*	*33.8*	*26.4*	*32.8*	*48.3*	*29.2*
18.3	67.5	94.9	87.2	70.0	100.0	89.7	72.5	100.0	89.7
	35.5	*33.3*	*69.7*	*59.3*	*61.6*	*75.3*	*69.7*	*68.0*	*81.0*
30.5	55.0	97.5	100.0	57.5	97.5	100.0	57.5	97.5	100.0
	27.8	*37.8*	*60.7*	*39.2*	*63.1*	*82.6*	*75.6*	*80.9*	*87.9*
42.7	47.5	82.1	83.8	57.5	87.2	94.6	57.5	89.7	94.6
	8.7	*24.6*	*25.9*	*9.6*	*41.3*	*59.0*	*32.8*	*49.0*	*68.0*
54.9	32.5	57.9	50.0	40.0	68.4	55.0	40.0	73.7	57.5
	0.7	*43.9*	*32.9*	*0.7*	*65.1*	*42.9*	*17.1*	*75.8*	*64.8*

Table 2. Percent mortality of adult female *Aedes taeniorhynchus* (not italicized) and *Culicoides furens* (italicized) exposed to ULV naled (Exp. 2).

Distance (m) from release point	Time (hr) after treatment								
	1			6			24		
	Height (cm)			Height (cm)			Height (cm)		
	15	91	183	15	91	183	15	91	183
9.1	4.5	13.3	38.7	4.5	19.4	52.2	9.4	17.7	51.2
	2.6	*0.0*	*7.5*	*0.5*	*2.6*	*10.6*	*16.6*	*4.9*	*13.2*
25.9	1.1	45.7	72.7	11.3	77.6	89.8	11.3	77.6	89.8
	5.1	*6.9*	*12.9*	*6.2*	*59.7*	*79.6*	*33.3*	*76.2*	*90.1*
42.7	5.3	29.2	40.6	16.7	45.0	50.5	16.7	47.8	50.5
	0.0	*0.0*	*14.6*	*9.2*	*17.3*	*52.6*	*23.4*	*51.4*	*67.6*
59.4	8.3	18.2	18.2	26.0	38.7	52.2	26.0	40.8	52.2
	9.1	*1.9*	*9.6*	*10.2*	*7.5*	*20.9*	*16.4*	*32.5*	*24.2*
76.2	16.1	12.9	16.8	16.1	12.9	16.8	17.9	12.9	16.8
	0.0	*2.4*	*4.6*	*0.0*	*5.3*	*5.7*	*9.4*	*22.8*	*12.0*

positions in Experiment 2 (Table 2). Results were very similar with the *Culicoides*, except that the mortality levels were somewhat lower, an effect ascribed earlier to reduced penetration of insecticide. Control remained fair out to the third poles in Experiment 1 (Table 1, Fig. 1), with no lower than 57.5% mortality among the test groups of *Ae. taeniorhynchus*, and 75.6% among *C. furens*. There was less effect in Experiment 2 (Fig. 2), with comparable lowest mortalities (Table 2) of 16.7 and 23.4%. As anticipated, the treatment had diminishing effect at progressively greater distances, as seen most clearly on the plotted data (Figs. 1,2). In comparing these figures it should be remembered that poles in Experiment 2 were further apart (e.g., pole pair 4 in Exp. 2 was further from the release point than pair 5 in Exp. 1).

With respect to cage height, a generally consistent pattern (Figs. 1,2) indicated that control effect diminished, or survival increased, at progressively lower elevations. The data demonstrate this effect more clearly if displayed as in Fig. 3, in which it is evident that survival was usually greatest in the lowest cages (15 cm). Since the wind-borne insecticide droplets would not have settled to ground along vertical paths, but rather at an angle, much of the chemical was presumably intercepted by grass stems and other low vegetation. There is some indication in Fig. 3 that cages at 91 cm were somewhat less affected than the highest ones at 183 cm, but the extent to which the lowest cages were least affected is much more obvious.

An important objective was to estimate, for this method of ULV naled application, the distance from the release point at which selected levels of survival occur. The data present some difficulty because survival was relatively high at the first poles, especially in Experiment 2 (Figs. 1,2), and lowest at the second poles, with larger proportions then remaining alive at progressively greater distances. Data for pole position two and beyond can therefore be evaluated by regression analysis, using the combined percentage survival data from all cage heights (at each pole position) and both experiments (Fig. 4). Highly significant linear regressions (slopes not significantly different) are obtained for both *Ae. taeniorhynchus* ($P < 0.02$, $r^2 = 0.666$) and *C. furens* ($P < 0.01$, $r^2 = 0.708$). The distances corresponding to selected survival levels are therefore easily calculated, but must be related to an estimated origin in terms of distance from the release point. Since survival was high at 9.1 m in Experiment 2 (Table 2), 10 m (from the release point) has been chosen as a reasonable estimate of the distance at which the linear survival trends in Fig. 4 originate. Obviously this represents a compromise between the two experiments, since the lowest survival may have been closer than 10 m in Experiment 1 (Fig. 1) and probably beyond it in Experiment 2 (Fig. 2). A matter of a few meters does not, however, affect the broad significance of conclusions that can be reached.

The distances (beyond 10 m) within which survival is equal to or less than 10, 30 and 50% are shown for the two species in Table 3. Since survival was consistently higher in cages at 15 cm elevation as opposed to 91 and 183 cm (Fig. 3), similar calculations were applied to the combined data grouped by cage elevation (Table 3). These figures provide an indication of survival that might be expected among insects resting in grass or other low vegetation, or in flight or at rest in more elevated, open sites. The overall estimate (all cage heights) shows that 10% survival (90% control) of *Ae. taeniorhynchus* was attained to only 5 m (beyond 10 m) and was not achieved at all for *C. furens*. For 30 and 50% survival, representing considerably poorer con-

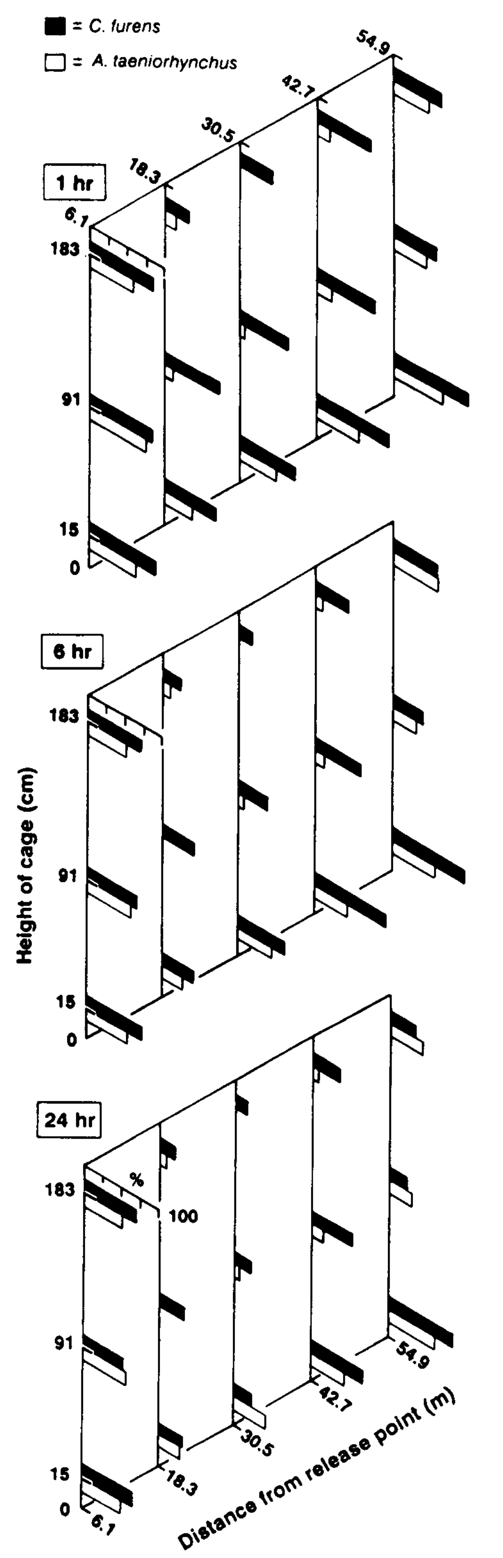

Fig. 1. Experiment 1: isometric plots of percent survival of *Aedes taeniorhynchus* and *Culicoides furens* (data from both pole lines combined) at 1, 6, and 24 hr after treatment.

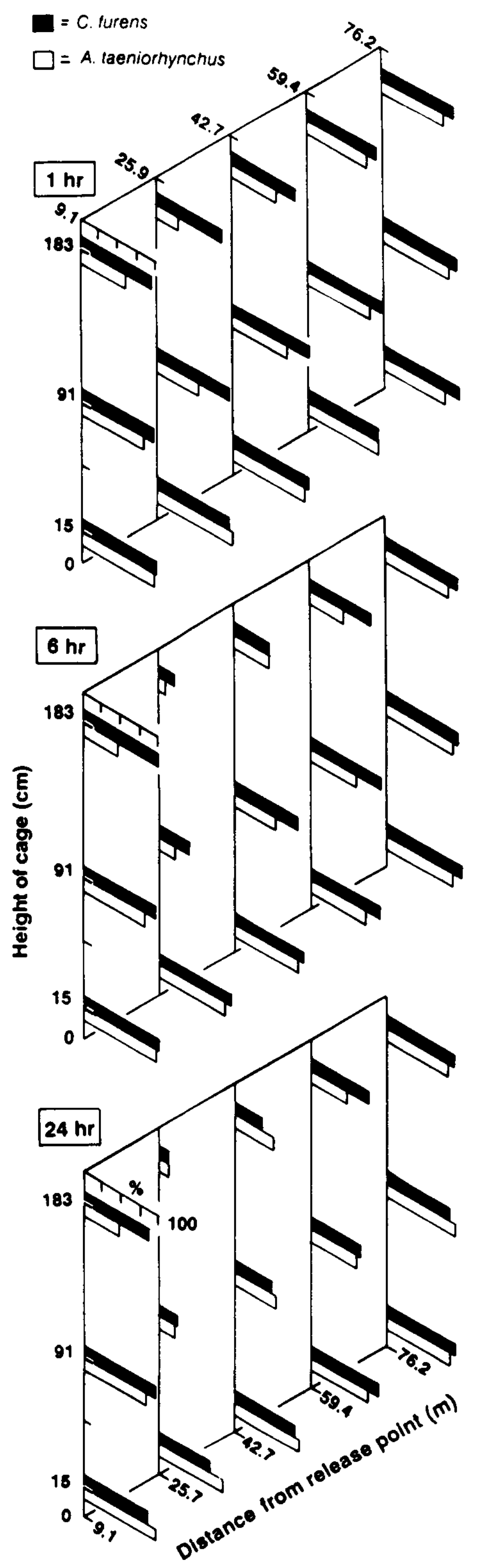

Fig. 2. Experiment 2: isometric plots of percent survival of *Aedes taeniorhynchus* and *Culicoides furens* (data from both pole lines combined) at 1, 6 and 24 hr after treatment.

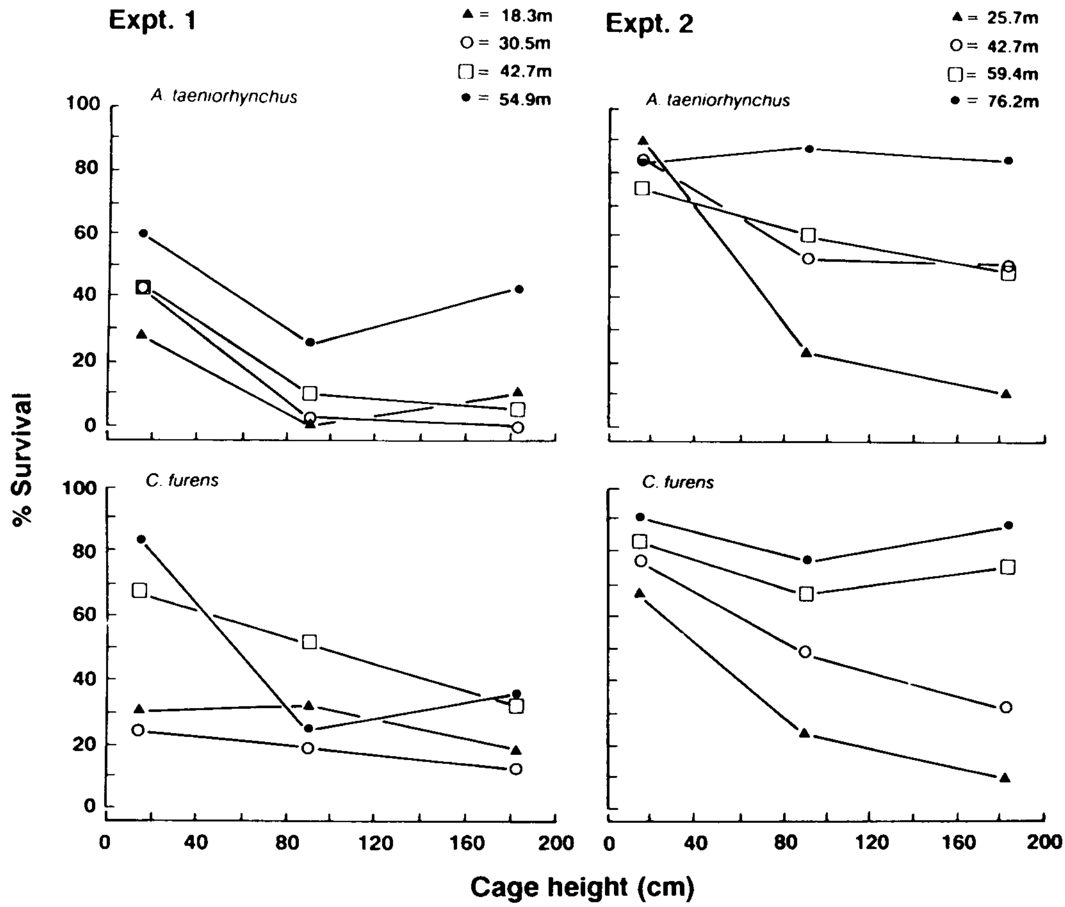

Fig. 3. Percent survival of *Aedes taeniorhynchus* and *Culicoides furens* in relation to cage height.

trol levels, the distances for the two species were 23 and 18 m, and 41 and 36 m, respectively. Considering insects very near the ground (15 cm cage elevation), survival in both species was not reduced below 30% at any distance, and was equal to or less than 50% only out to 12 and 19 m (beyond 10 m), respectively. Survival was considerably lower at 91 to 183 cm, but was equal to or less than 10% only to a distance of 18 m for *Ae. taeniorhynchus* and 8 m for *C. furens* (Table 3). These results can also be visualized more practically as "swaths of control" running parallel to and starting at about 10 m from the line of spray release. Thus, the overall estimate indicates that 70% control, or better, occurred within a swath 23 m (25 yd) wide and 18 m (19.7 yd) wide, respectively, for the two species.

DISCUSSION

At the dosage rate used here, which is that routinely applied in Sarasota County mosquito abatement operations, it is easily calculated that for an assumed swath width of 91.4 m (300 ft), the dosage was 0.14 oz naled/acre (active ingredient) when 85% concentrate is dispensed at 6 oz/linear mile. As shown, this treatment achieves relatively poor control of caged female *Ae. taeniorhynchus* and *C. furens*, with 70% mortality occurring only within a swath 23 and 18 m wide (originating at about 10 m from the release point) for the two species, respectively. Control of 90% or better extended only to 5 m in the case of *Ae. taeniorhynchus*, and was not attained at all in the case of *C. furens*.

In earlier experiments with caged *Ae. taeniorhynchus*, Mount et al. (1968) reported (top line of their Table 3) 76 and 58% mortality (18 hr after treatment) at distances of 45.7 and 91.4 m (150 and 300 ft) from the release point and 24% mortality as far as 182.9 m (600 ft). Since the dosage rate (given as 0.0045 lb/acre) for these particular data was essentially the same as used here, it is apparent that our tests yielded poorer control. Our results imply, for example (Fig. 4), that 58% mortality, recorded by Mount and co-workers at 91.4 m (300 ft), would extend to only 43.4 m (142.5 ft). One factor contributing to the difference may have been droplet size. As compared to the 13.5 μm mmd size dispensed in our tests, Mount et al. (1968), insofar as can be estimated from their paper, were probably working with smaller droplets in the 6–8.5 μm mmd range, which they found to be consistently more effective. Another consideration is that their insects were suspended 1.5 m (5 ft) above ground, equivalent to the higher cage elevations in our work (Table 3), at which wider swaths of control were obtained. Based on the two higher cages, our data project 58% control out to 50.8 m (166.7 ft) compared to 91.4 m (300 ft) reported by Mount and co-workers. Midges and mosquitoes at rest in low vegetation are a significant consideration, however, and they are very poorly controlled by ULV naled applied as described (Table 3). Since our tests were carried out with caged insects (as were those by Mount et al. (1968)), it can be assumed that the cage mesh in each case reduced the amount of insecticide making contact with the insects and thus diminished the apparent effectiveness of the treatment. This factor may also have contributed slightly to the superior survival of *C. furens*, since the mesh in their cages presented 54.8% open area to the passage of insecticide, as opposed to 57.4% for the mosquito cages.

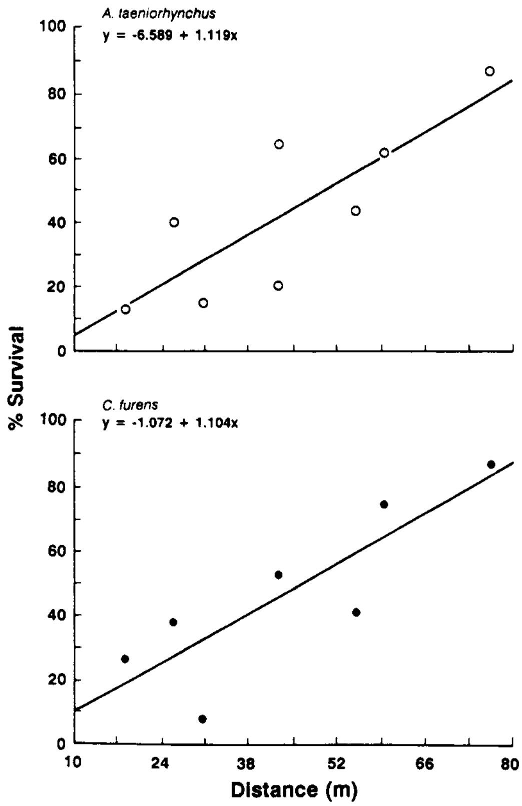

Fig. 4. Regressions of percent survival of *Aedes taeniorhynchus* and *Culicoides furens* on distance (data from all cage heights combined) from an origin 10 m away from the line of spray release. Data from the first pair of poles in each experiment omitted (see text).

In contrast to ground applications, aerial treatments of ULV naled, at appropriate dosages, appear to be extremely effective against both mosquitoes and *Culicoides*. Haile et al. (1984) found that two applications, on successive days, gave extremely effective control of several mosquito species and *C. hollensis* (predominantly) at 1 oz/acre, but relatively poor results at a dosage of 0.25 oz/acre. Similarly, Giglioli et al. (1980) obtained excellent abatement of a mixed population of *C. furens* (primarily) and *C. barbosai* Wirth and Blanton with aerially applied fenitrothion at 2.7 oz/acre. These treatments clearly produced excellent control, but the aerially applied naled (Haile et al. 1984) was dispensed at 7.1 × the dosage per acre compared to the ground applications reported here or by Mount et al. (1968).

In conclusion, the results we have described suggest that ULV naled, applied by vehicle-mounted equipment at 0.14 oz/acre, droplet size

Table 3. Predicted distances (m) beyond 10 m from release point, where survival would be equal to or less than percentage indicated.

Cage heights	Species	Distance (m) beyond 10 m where survival equal to or below percentage indicated		
		10%	30%	50%
1. All heights combined	*Ae. taeniorhynchus*	5	23	41
	C. furens	0	18	36
2. 15 cm only	*Ae. taeniorhynchus*	0	0	12
	C. furens	0	0	19
3. 91 and 183 cm	*Ae. taeniorhynchus*	18	32	47
	C. furens	8	26	45

13.5 μm mmd, does not control *Ae. taeniorhynchus* and *C. furens* particularly effectively. Insects resting in low vegetation close to the ground appear to be very poorly controlled. The disparity of these results with respect to those obtained in similar, previously published tests (Mount et al. 1968) seems most likely to be at least partly due to the smaller droplet size used in the earlier experiments.

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