AERIAL ADULTICIDING FOR THE SUPPRESSION OF *CULEX TARSALIS* IN KERN COUNTY, CALIFORNIA, USING LOW VOLUME PROPOXUR: 2. IMPACT ON NATURAL POPULATIONS IN FOOTHILL AND VALLEY HABITATS.

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ABSTRACT. A low volume formulation of propoxur wettable powder suspended in larvicidal oil was evaluated on 4 occasions in Kern Co., California during 1983 using fixed and rotary wing aerial application systems. *Culex tarsalis* abundance was suppressed significantly by all sprays, although reduction below the virus maintenance threshold of 30 females per trap night was achieved only at one foothill site. Western equine encephalomyelitis virus minimum infection rates decreased significantly after serial applications on 2 occasions at a valley site. However, virus persisted in the spray zone at minimum infection rates of > 1 per 1000 *Cx. tarsalis* females tested and transmission of virus to sentinel chickens continued. The parity rates were reduced significantly at 2 semi-isolated foothill sites, but not at a valley site where elevated autogeny rates increased the reproductive age of the host-seeking population. Spraying during late afternoon by helicopter resulted in better control than early morning applications by fixed wing aircraft at a valley site.

INTRODUCTION

Aerial adulticiding is currently the most effective method of eliminating infected female mosquitoes from a large area in a short time period to interrupt epidemic transmission of western equine encephalomyelitis (WEE) or St. Louis encephalitis (SLE) viruses. Research in 1982 indicated that numerical suppression of *Culex tarsalis* Coquillett could be achieved by ULV formulations applied to small areas (<360 ha.) by single engine, fixed-wing aircraft, provided that the target population was susceptible and exposed to the spray, and that the population addition rate was relatively low (Reisen et al. 1984). However, control in a mixed agricultural habitat was seriously hindered by resistance to organophosphate (malathion, chlorpyrifos) and pyrethroid (resmethrin) insecticides in laboratory bioassays and field cage exposures (Yoshimura et al. 1983). With the arsenal of ULV adulticides registered for aerial application essentially depleted, research in 1983 emphasized the evaluation of propoxur (Schaefer et al. 1985). Unfortunately, sufficient quantities of the Baygon MOS–1 ULV formulation were not available for the planned area treatments, and thus adulticiding was done with a low volume formulation of propoxur wettable powder suspended in larviciding oil.

The present report compares the impact of fixed and rotary wing aerial applications of a low volume propoxur formulation on *Cx. tarsalis* populations at 3 habitats. Emphasis was placed on comparatively evaluating the impact of different adulticiding methods on relative abundance, reproductive status, and arboviral infection rates. A companion paper (Schaefer et al. 1985) describes the spray equipment, formulation, effectiveness of coverage and field dosage rates.

METHODS AND MATERIALS

APPLICATION. Propoxur 70% wettable powder was suspended in Witco Golden Bear larvicide oil and applied at the maximum label rate of 0.078 kg of active ingredient per ha. (0.075 lbs/acre) as described by Schaefer et al. (1985). Fixed-winged applications were made by the Kern Mosquito Abatement District using an Ayres Thrush Commander, while rotary wing applications were made by the U.S. Army using a Simplex Model 6800 underslung spray unit tethered beneath a Bell UH–1 helicopter (Schaefer et al. 1985). *Culex tarsalis* from all target populations and the reference *Br80* colony were susceptible to propoxur in laboratory contact filter paper and field cage exposures (Parman et al. 1984). Effective coverage of the target area was indicated by mortality patterns of sentinel mosquitoes exposed along transects and on CO_2 trap standards within the spray zone (Schaefer et al. 1985).

DESCRIPTION OF STUDY AREAS. During 1983, aerial applications of propoxur were evaluated at two foothill (Poso West, Breckenridge) and one mixed agricultural valley habitat (John Dale) situated near Bakersfield, Kern Co., California (Schaefer et al. 1985). The Poso West and Breckenridge sites were semi-isolated by surrounding arid grassland, while John Dale was part of an agricultural continuum encom-

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passing most of the southern San Joaquin valley floor. The presence of fodder crops approaching harvest stage forced us to shift the spray zone at John Dale 1.6 km to the W for the early morning fixed-wing application. The new spray zone encompassed the Los Pobrecitos Gun Club which consisted of reclaimed and irrigated pasture and retained 65 ha to the E which included Mosesian's Duck Club. The flooding of both clubs at the start of hunting season led to mosquito production within the spray zone during September.

EVALUATION. Aerial applications were evaluated using a 23 day protocol developed during 1982 with spraying done on days 9, 12, and 15 (Reeves et al. 1983). Host-seeking females were sampled by 16 or more CDC miniature traps operated without lights and augmented with 1–2 kg of dry ice (CO_2 trap). Traps were arranged along N–S and E–W intersecting transects, with 4 comparison traps positioned > 1.5 km outside the border of the spray zone and 12 traps positioned within the spray zone. Additional host-seeking females were collected at John Dale by CO_2-baited, time-segregated samplers (TSS) which segregated nightly catches into hourly intervals (Meyer et al. 1984). Suppression of host-seeking female abundance below a theoretical threshold value of 30 females per trap night was considered necessary to interrupt virus transmission (Reisen et al. 1984).

Resting mosquitoes were sampled concurrently with trap pick-up using small (Goodwin 1942) and large walk-in (Nelson and Spadoni 1972) red boxes. At Poso West, resting adults were collected from 8 pipe traps (Nelson 1980) and egressing adults were taken in 10 cone traps placed over the entrances to rodent burrows.

Trap placement was modified at Poso West and Breckenridge because irregular terrain limited access. At Poso West a comparison trap could not be positioned to the east, and additional CO_2 traps were placed within the spray zone along Poso Creek and at Mcvan, an ecologically similar, but unsprayed, comparison area located ca. 5 km N of the spray zone. The Breckenridge site consisted of 3 relatively parallel canyons, A, B and C (Milby et al. 1983). Trap placement was modified with 8 traps positioned in sprayed canyon B and 3 traps placed in each of unsprayed canyons A and C.

At John Dale, Mosesian's Duck Club, a heavily vegetated site in the center of the spray zone, served as a settlement area for adult mosquitoes emerging from peripheral breeding sites (Reisen et al. 1984). Time-segregated-samplers and walk-in red boxes were positioned at Mosesian's Duck Club and Costerisan's farm headquarters, a comparison site 4 km to the NW.

Adult *Cx. tarsalis* were dusted with cohort specific fluorescent colors (Nelson et al. 1978) and were released in the center of each spray zone, 4 and 1 days before the 1st spray. Marked mosquitoes were considered to be unrestrained sentinels and control was implied from differential recapture patterns following the 2 releases. When available, distinctively marked females were released in comparison areas to study infiltration into the spray zone.

The reproductive status of the target population was monitored by dissecting 10 host-seeking females from each of 4 central spray zone and 4 comparison zone traps, and 40 resting females collected from shelters in the spray and comparison zones. Spermathecae were examined for spermatozoa. Ovarian maturation was classified by the scheme of Christophers (1911) as modified by Mer (1936). Parity was determined by the degree of tracheole coiling and the presence of dilatations (Detinova 1962). To determine autogeny status, females emerging from field-collected pupae were offered 10% sucrose in the insectary for >8 days and then dissected to determine the degree of follicular maturation. Females with primary follicles at > Stage III were considered autogenous.

Female *Cx. tarsalis* collected by spray and comparison zone CO_2 traps were tested for arbovirus infection during pre- and postspray periods. Mosquitoes were sorted into pools of up to 50 females each, frozen immediately at −70°C, and shipped to the Viral and Rickettsial Diseases Laboratory, California Department of Health Services, Berkeley for viral assay in suckling mice. Mosquitoes collected concurrently at 3 rural sites west of Bakersfield were tested for virus as a comparison. A sentinel chicken flock maintained near the valley site was bled at monthly intervals to monitor arbovirus transmission activity by seroconversion.

Percent population reduction was calculated using Mulla's formula (Mulla et al. 1971) which compares changes in mean abundance within the spray zone pre- and postspray to concurrent changes in mean abundance within the comparison zone. Changes in mean abundance and reproductive status over time were evaluated by T-test and heterogeneity χ^2, respectively (Sokal and Rohlf 1969).

RESULTS

FIXED WING, AFTERNOON SPRAY AT POSO WEST. Recapture rates among 3 cohorts released in the center of the spray zone decreased markedly after each spray indicating good kill within the spray zone (Table 1, Fig. 1a). Sufficient specimens were not available for releases in the comparison zone to study immigration.

The number of females resting in red boxes and pipe traps and egressing from rodent burrows declined significantly after the first spray and remained low during the spray and postspray periods (Fig. 2). The relative abundance of host-seeking females within the spray zone decreased significantly from a mean of 90 *Cx. tarsalis* females per trap night prespray to 24 during the spray period. Relative abundance remained below 30 females per trap night at 4 central spray traps during the spray period, but again exceeded this threshold value by June 30, 6 days postspray. The relative abundance of females at traps within the spray zone was correlated significantly with female abundance at traps within the comparison zone ($r = 0.67$, $n = 14$), but not at the more distant (Mcvan comparison area ($r = 0.45$, $n = 7$). The reduction of host-seeking females at sprayed trap sites based on comparison traps was only 35%, while the reduction based on Mcvan traps was a more realistic 88% (Table 2).

Adulticiding significantly reduced the parity rate of host-seeking females from 44% prespray to 22% postspray (Table 2). A concurrent decrease in age structure was not observed at comparison traps. The parity rate among resting females was 27% prespray, decreased to 4% postspray, and was still only 9% 2 wks postspray. The parity rate among trapped females recovered more rapidly than the parity rate among resting females. Coincidentally, the insemination rate among resting females within the spray zone was 83, 64, 26 and 34% in prespray, spray, postspray and 2 wks postspray samples, respectively ($\chi^2 = 42.9$, $P < 0.01$). The decline in the insemination rate was related to the emergence of young females within the study area and the selective elimination of sexually mature males by the spray. The sex ratio (males/total) of resting *Cx. tarsalis* collected during the same time periods was 0.67, 0.23, 0.45 and 0.58, respectively. Alteration of the sex ratio was related to increased male mortality and presumably a comparatively low male immigration rate. Coincidental changes occurred in ovarian developmental stages. The percentage of unfed females with 1° follicles at Stages <IIa was 60, 49, 79 and 63%, respectively. The decrease in young females occurred concurrently with an increase in the proportion of gravid females collected during the spray period. The increase in young females postspray

Table 1. Release and recapture of *Culex tarsalis* adults during 4 spray evaluations in Kern County, California, 1983.

	Release					No. released			Recapt. (%)[5]	
Site	Genotype[1]	Source[2]	No.	Zone[3]	Date	♀	♂	% Aut.[4]	♀	♂
Poso West	PWW	L, P	1	spray	Jun 13	1523	1837	34	1.31	0.0
			2	spray	Jun 16	4705	4052	6	0.74	0.0
			3	spray	Jun 19	4294	3761	12	0.58	0.0
Breck.	BrW	L, P	1	spray–B	Jul 18	9729	10267	50	4.79	1.02
		CO_2 T+L, P	2	comp.–A	Jul 21	11074	3139		6.43	7.30
		CO_2 T+L, P		spray–B	Jul 21	14394	3640	16	1.06	0.47
		CO_2 T+L, P		comp.–C	Jul 21	11076	2156		3.93	0.09
John Dale	BrW	L, P	1	spray	Aug 12	4475	1851	52	2.06	2.11
		L, P	2	spray	Aug 15	3547	2751	76	1.41	0.36
		CO_2 T		comp.–E	Aug 15	1119	0		0.09	0.0
		CO_2 T		comp.–W	Aug 15	1391	0		0.79	0.0
		CO_2 T		comp.–S	Aug 15	1264	0		0.63	0.0
		CO_2 T		comp.–N	Aug 15	1228	0		0.57	0.0
John Dale	JDWf1	reared	1	spray	Sep 8	1902	1870	77	1.26	3.26
	BrW	CO_2 T+RB	2	spray	Sep 11	6844	1252		3.71	0.56
		CO_2 T		comp.–E	Sep 11	3916	0		2.37	0.0
		CO_2 T		comp.–W	Sep 11	3401	0		0.65	0.0
		CO_2 T		comp.–S	Sep 11	3441	0		1.66	0.0
		CO_2 T		comp.–N	Sep 11	4226	0		0.21	0.0

[1] PW = Poso West, Br = Breckenridge, JD = John Dale, W = wild-caught, f1 = progeny of wild-caught females reared in outdoor ponds.

[2] L, P = field-collected immatures, CO_2 T = females collected from CO_2 baited traps, RB = males and females collected resting in red boxes.

[3] Releases made in the center of the spray zone or at comparison zone standards positioned >1.5 km outside the spray zone; A, B & C refer to canyons at Breckenridge.

[4] Percentage of emerging females (n = 50) developing their eggs autogenously under insectary conditions.

[5] Percentage of released mosquitoes recaptured in both spray and comparison zones.

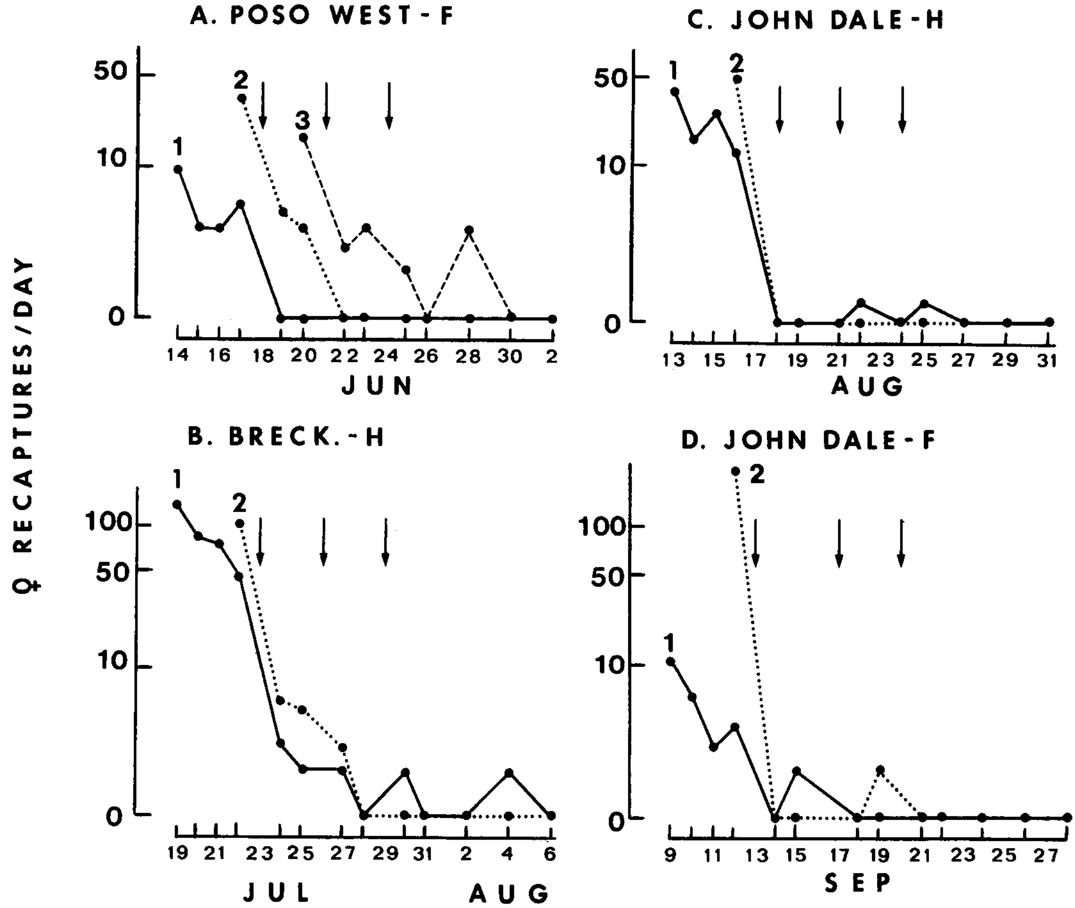

Fig. 1. Recapture patterns of marked *Culex tarsalis* females released 4 and 1 days prespray during evaluations of propoxur applied by fixed-wing aircraft (F) and helicopter (H) at Poso West (A) Breckenridge (B) and John Dale (C,D) in Kern County, CA, 1983 (arrows indicate the dates of spray).

reflected recruitment by emergence, since the spray did not kill immatures (Schaefer et al. 1985). Thus, the shift in female reproductive status was attributed to the elimination of older females by the spray and the continuous recruitment of nullipars by emergence within the spray zone. Western equine encephalomyelitis virus was not isolated from 2,250 *Cx. tarsalis* females (45 pools) tested during pre- and postspray periods.

ROTARY WING, AFTERNOON SPRAY AT BRECKENRIDGE. Recapture rates among females released in canyon B declined dramatically after the initial spray (Table 1, Fig. 1b). In addition to the 2 groups released in canyon B, distinctively marked adults were released in canyons A and C concurrent with release 2 (Table 1). Recapture patterns among marked dispersives indicated considerable mixing among the populations of all 3 canyons (Table 3). The recapture rate of emigrants from canyon B, but not canyons A and C, declined markedly following the 1st spray. The continued recapture in canyon B of females released in canyon B was attributed, in part, to the migration of dispersives back into canyon B after initially emigrating to unsprayed canyon C and, to a lesser degree, canyon A. Males dispersed less frequently than did females.

The relative abundance of females in sprayed canyon B decreased significantly during the spray period (Fig. 3). The relative abundance of females trapped in unsprayed canyons A and C decreased concurrently with female abundance in canyon B, r = 0.83 and 0.95, respectively. Using abundance in canyon A for comparison, the reduction in the central canyon B was estimated to be 73% for resting and 72% for host-seeking females. A marked reduction of 97% was estimated for less dispersive resting males. However, postspray abundance in the sprayed canyon remained well above the threshold of 30

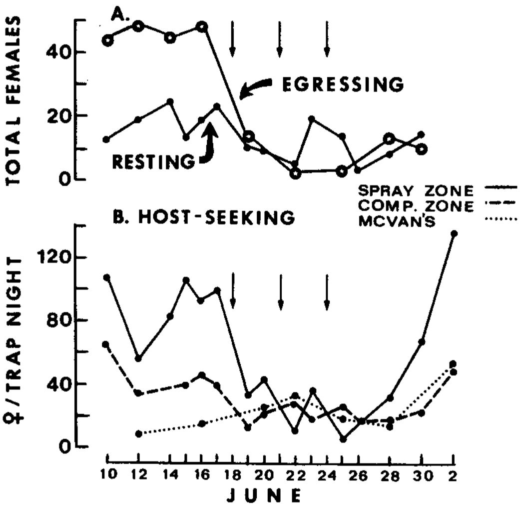

Fig. 2. Relative abundance of *Culex tarsalis* females resting in small red boxes and egressing from rodent burrows, and host-seeking at CO_2 traps at Poso West and McVan, Kern Co., CA, during afternoon fixed-wing applications of low volume propoxur in 1983 (arrows indicate the dates of spray).

females per trap night considered theoretically necessary to maintain virus transmission. Arboviruses were not isolated from 20 pools of *Cx. tarsalis* (n = 1,000 females).

Parity rates among resting and host-seeking females in canyon B were 36 and 26% prespray, and 4 and 1% postspray, respectively (Table 2). The virtual elimination of parous females indicated that infected mosquitoes would have been removed and transmission possibly interrupted, even though relative abundance remained above the desired threshold level. Insemination rates and ovarian stages did not change appreciably over time in canyon B, since most females dissected postspray were immigrants from canyon C and, to a lesser degree, canyon A (Table 3).

ROTARY WING, AFTERNOON SPRAY AT JOHN DALE. The effectiveness of the spray was indicated by a marked decline in the recapture rate of dusted mosquitoes released 4 and 1 days before spray 1 (Table 1, Fig. 1c). The recapture rates of females released at comparison standards were <1% (Table 1) and only 5 of these females were recaptured within the spray zone (4 prespray and 1 postspray).

Table 2. Percentage parity (number dissected) among resting and host-seeking *Culex tarsalis* females collected during 4 spray evaluations in Kern County, California, 1983.

Location–Aircraft[1]	Collection Zone[2]–Method[3]	Pre	Spray	Post	2-wk post	χ^{2}[4]
Poso West—F	spray-resting	27 (78)	14 (71)	4 (85)	9 (58)	20.6***
	spray–CO_2 T	44 (120)	24 (200)	22 (172)	50 (60)	32.5***
	comp.–CO_2 T	27 (112)	35 (153)	24 (133)	nd	4.8ns
Breckenridge—H	spray (B)–RB	36 (50)	18 (95)	4 (50)	nd	16.8***
	comp. (A)–RB	36 (50)	31 (75)	8 (50)	nd	11.9**
	spray (B)–CO_2 T	26 (185)	22 (233)	1 (160)	50 (30)	58.9***
	comp. (A)–CO_2 T	32 (60)	31 (90)	2 (60)	40 (20)	23.4***
John Dale—H	spray–RB	77 (99)	61 (115)	69 (48)	nd	6.2*
	Cost.–RB	66 (91)	66 (128)	51 (39)	nd	3.2ns
	spray–CO_2 T	84 (85)	63 (75)	90 (50)	nd	15.8***
	comp.–CO_2 T	84 (45)	69 (75)	78 (50)	nd	3.7ns
	spray–TSS	68 (80)	nd	69 (54)	nd	0.1ns
	Cost.–TSS	67 (75)	nd	74 (42)	nd	0.6ns
John Dale—F	spray–RB	66 (124)	58 (155)	40 (95)	52 (25)	15.5**
	Cost.–RB	66 (50)	70 (70)	50 (28)	nd	3.6ns
	spray–CO_2 T	70 (50)	69 (150)	84 (75)	nd	5.9ns
	comp.–CO_2 T	80 (50)	76 (74)	60 (50)	nd	5.7ns
	spray–TSS	92 (100)	48 (42)	nd	86 (86)	40.5***
	Cost.–TSS	85 (20)	nd	71 (17)	nd	1.1ns

[1] F = fixed wing, H = helicopter.

[2] Spray = center of spray zone area, comp. = comparison zone traps >1 km outside the spray zone, Costerisan (Cost.) = comparison area >4 km to N of spray zone.

[3] Method: resting = females collected from small red boxes, pipe traps and cone traps, CO_2 T = CO_2 baited CDC traps, RB = walk-in red box, TSS = time-segregated sampler, nd = none dissected.

[4] Heterogeneity χ^2, ns = $P>0.05$, * $0.01<P<0.05$, ** $0.001<P<0.01$, *** $P<0.001$.

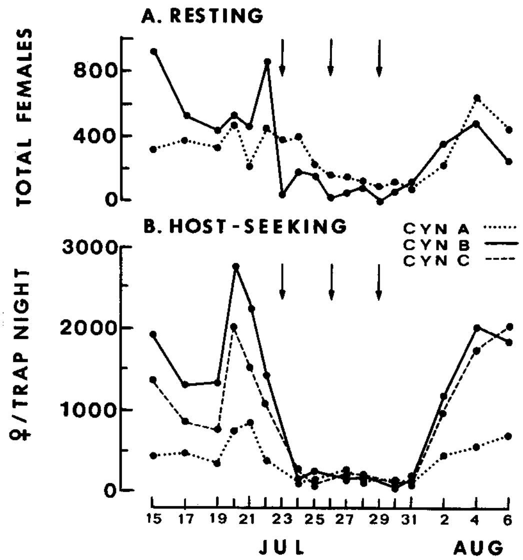

Fig. 3. Relative abundance of *Culex tarsalis* females resting in walk-in red boxes and host-seeking at CO_2 traps in 3 canyons during afternoon helicopter applications of low volume propoxur at Breckenridge, Kern Co., CA, 1983 (arrows indicate the dates of spray).

Culex tarsalis female abundance within the spray zone decreased significantly during the spray period (Fig. 4), although abundance at the central sprayed traps never declined below 30 females per trap night. Female abundance at comparison zone traps declined coincidentally with abundance at spray zone traps, r = 0.83. In contrast, female abundance at red boxes and at the time-segregated-sampler situated at Costerisan's was not correlated over time with abundance within the spray zone, r = 0.31 and −0.13, respectively. Reduction was 44% when abundance at sprayed traps was compared to comparison traps, but was 83 and 86% when resting and time-segregated-sampler collections within the spray zone were compared to those at Costerisan's. The estimated reduction for resting males was 96%, slightly higher than for resting females.

Table 3. Total numbers of marked *Culex tarsalis* recaptured in sprayed canyon B and comparison canyons A and C during the afternoon helicopter evaluation at Breckenridge, Kern County, California, 1983.

Recapture canyon	Collection period	Release canyon B ♀/♂	Release canyon A+C ♀/♂
A	prespray	55/1	394/140
	spray	5/1	234/87
	postspray	0/0	0/1
B	prespray	439/103	184/2
	spray	17/9	107/1
	postspray	1/0	1/0
C[1]	prespray	85	155
	spray	7	71
	postspray	0	1

[1] No walk-in red box in canyon C so males not sampled.

Parity rates for females from red box, CO_2 trap or time-segregated-sampler collections were altered significantly by spraying, but remained >50% throughout (Table 2). High parity rates also occurred in females from comparison zone traps as well as from red box and time-segregated-sampler collections at Costerisan's. High parity rates were attributed to elevated autogeny rates observed in females collected as pupae from an irrigated pasture (80%, n = 34) and from sewer farm run-off (82%, n = 50).

The WEE minimum infection rate (MIR) for *Cx. tarsalis* collected at both spray and comparison zone traps declined significantly (P<0.01) from 6.3 and 6.8 per 1000 females tested prespray to 1.5 and 1.9 postspray, respectively (Table 4). Western equine encephalomyelitis MIR's measured concurrently at 3 westside sites were 6.3 and 5.5 pre- and postspray, respectively. A flock of 25 sentinel chickens was established near the western border of the spray zone and was bled on July 25, August 29 and September 26. The percent of birds with WEE antibodies on each date was 5, 57 and 86, respectively, indicating that transmission continued despite decreases in the MIR.

FIXED WING, EARLY MORNING SPRAY AT JOHN DALE.' Effective control was indicated by the marked postspray decline in the recapture rate of mosquitoes released within the spray zone (Table 1, Fig. 2d). Concurrent with release 2, a total of 14,984 distinctively marked females were released at the 4 comparison zone standards (Table 1). Recapture rates for peripherally released females were higher than observed during Aug (Table 1) and 24 marked females were recaptured within the spray zone. Of these, 8 immigrants from the S and W were recaptured within the spray zone after the 1st spray indicating that immigration occurred downwind with the prevailing WSW winds.

Culex tarsalis relative abundance within the spray zone decreased significantly during the spray period (Fig. 4). The abundance of host-seeking females was not reduced to below the 30 females per trap night considered necessary to maintain virus transmission. Abundance at comparison traps, red boxes, and time-segregated-sampler collections did not change or increased significantly, agreeing with the

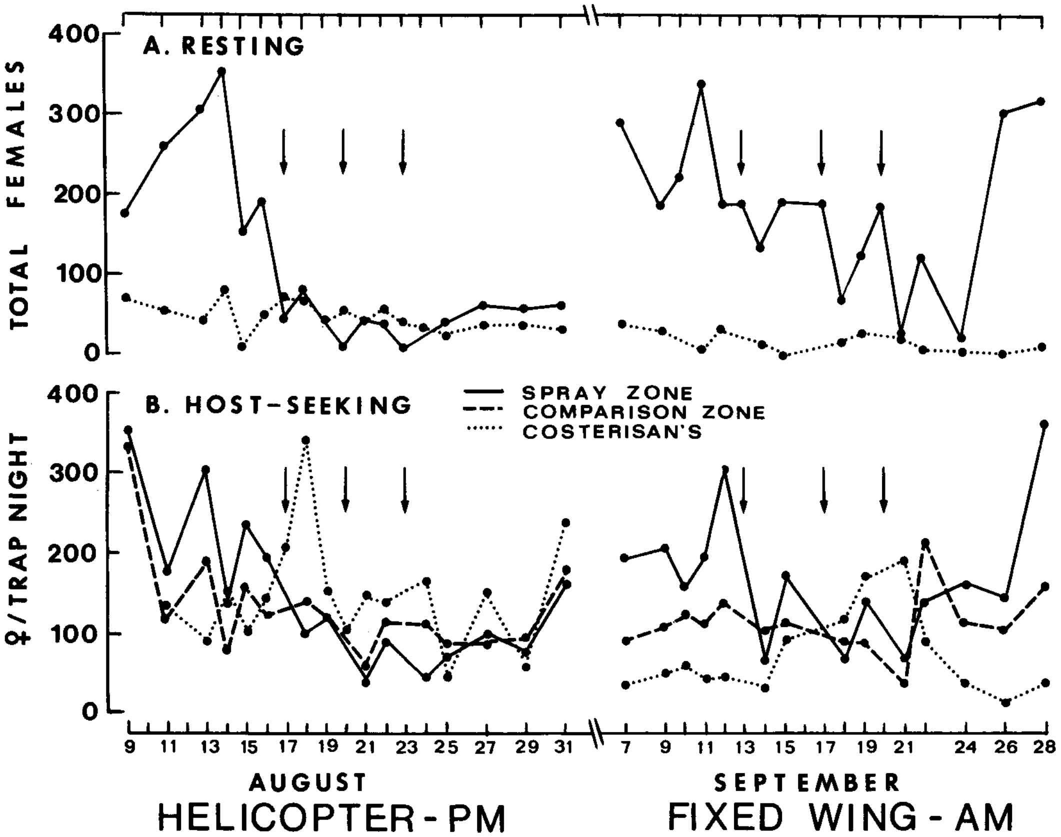

Fig. 4. Relative abundance of *Culex tarsalis* females resting in walk-in red boxes and host-seeking at CO_2 baited traps and a time segregated sampler (TSS) during afternoon helicopter and early morning fixed-wing applications of low volume propoxur at John Dale and Costerisan's Farm headquarters, Kern Co., CA, 1983 (arrows indicate the dates of spray).

persistence of marked females recaptured at comparison zone traps. Abundance at red boxes, CO_2 traps and the time-segregated-sampler within the spray zone was not correlated significantly with abundance at comparison zone traps ($r = 0.43$), or the red box ($r = -0.17$) and time-segregated-sampler ($r = -0.49$) at Costerisan's.

Reduction of females collected by spray and comparison zone traps, and resting and time-segregated-sampler collections within the spray zone and at Costerisan's was 45, 27 and 75%, respectively. The reduction in male abundance also was low (31%). The percent reductions achieved by morning fixed-wing applicati[illegible] were less than those achieved by afternc[illegible] rotary-wing sprays.

Changes in the parity status of femal[illegible] collected by different methods were variable, decreasing significantly in red boxes and tir[illegible] segregated-sampler collections in the spr[illegible] zone, remaining unaltered at Costerisan's and comparison traps, and increasing at spray zone traps (Table 2). Decreases in parity were attributed to a general increase in the emergence rate from breeding sites created by duck club flooding and not necessarily to the selective elimination of older females by effective spraying. The percentage of empty females at <Stage IIa decreased from 61% prespray to 39% postspray when more gravid females were collected coincidental with the flooding of the gun clubs. The proportion of empty females increased to 77% 2 wks postspray.

The WEE MIR at sprayed traps decreased significantly from 4.8 to 1.3 per 1000 female *Cx. tarsalis* pre- and postspray, respectively, while the MIR at comparison standards remained unaltered (Table 4). The decrease in the MIR within the spray zone, but not in the comparison zone, agreed with the trends in the relative abundance and age structure. Western equine encephalomyelitis virus activity at the westside sites was comparatively low, but did not decrease concurrently with the spray at John Dale. Sentinel chickens were bled too close to the

Table 4. Isolation rate of western equine encephalomyelitis (WEE) virus from *Culex tarsalis* collected in spray and comparison zones at John Dale and at 3 westside locations in Kern County, California, 1983.

Aircraft-time period	Time period	Site	Zone	No. tested (no. pools)	WEE isolates[1] (MIR)
Rotary-wing–PM	prespray	JD	spray	950 (19)	6 (6.3)
			comp.	585 (12)	4 (6.8)
		WS[2]	—	1750 (35)	11 (6.3)
	postspray	JD	spray	1350 (27)	2 (1.5)
			comp.	1050 (21)	2 (1.9)
		WS	—	2350 (47)	13 (5.5)
Fixed wing–AM	prespray	JD	spray	1050 (21)	5 (4.8)
			comp.	200 (4)	1 (5.0)
		WS	—	2350 (47)	6 (2.6)
	postspray	JD	spray	750 (15)	1 (1.3)
			comp.	350 (7)	2 (5.7)
		WS	—	2300 (46)	8 (3.5)

[1] MIR = minimum infection rate per 1000 *Cx. tarsalis* females tested.
[2] WS = west side comparison areas (Eureka Duck Club, Smith's Pasture and Kern National Wildlife Refuge) sampled weekly.

spray period to reflect changes in the cumulative seroconversion rate.

DISCUSSION

COMPARATIVE EFFECTIVENESS OF MORNING AND AFTERNOON SPRAYS. Aerial applications of a low volume formulation of 70% propoxur wettable powder in larvicidal oil significantly reduced *Cx. tarsalis* abundance in both foothill and valley habitats when applied by either fixed- or rotary-wing aircraft. Afternoon sprays at John Dale by helicopter seemed to more effectively control *Cx. tarsalis* than did early morning sprays by fixed-wing aircraft at the same site. Population reductions were greater and suppression was more rapid during afternoon than morning sprays. In contrast, mortality among sentinels was higher during the morning than the afternoon spray, indicating that coverage and/or the effects of weather factors did not decrease treatment effectiveness (Schaefer et al. 1985). Both aircraft types gave comparable control during late afternoon sprays over foothill terrain, indicating the observed differences could not be attributed to spray dispersal or droplet size spectrum. Red box collections in the spray zone made 1 hr after the early morning sprays indicated limited kill among resting mosquitoes, although decreases in resting abundance were observed the following morning, 24 hr postspray. However, suppression of resting abundance was observed the morning after evening sprays, ca. 12 hr postspray.

Presumably the large droplets applied during the present study settled rapidly (Schaefer et al. 1985), and thus mortality occurred when mosquitoes egressing from diurnal shelters contacted spray deposits on vegetation. Since *Cx. tarsalis* are inactive diurnally, adulticides applied during early morning were exposed to sunlight and warm temperatures for 12–16 hr prior to possible contact with mosquitoes egressing from resting sites during the following dusk. In contrast, mosquitoes egressing from resting sites would contact afternoon sprays 1–3 hr postspray after minimal exposure to sunlight. Therefore, asynchrony between mosquito activity patterns and the timing of application rather than differences in spray systems most likely resulted in the improved control by the late afternoon spray. Although weather conditions were operationally more favorable during morning (Schaefer et al. 1985), our results indicated that afternoon sprays were superior for *Cx. tarsalis* control. Similar asynchrony between mosquito activity and spray timing may have contributed to the limited suppression achieved by morning malathion sprays for *Cx. tarsalis* control in Hale Co., Texas (Mitchell et al. 1970).

ENHANCED CONTROL BY TREATING SETTLEMENT AREAS. The central spray zone at all 3 study areas consisted of favorable resting habitat which formed a settlement area for adults emerging from peripheral breeding sites. Suppression of adults within the central spray zone during late afternoon sprays was accompanied by concurrent declines in the abundance of host-seeking females at comparison standards within 2.5 km of the spray zone, even though spray drift to comparison traps occurred only once at Poso West (Schaefer et al. 1985). Traps and/or red boxes positioned >4 km distant at McVan and Costerisan's did not exhibit changes in abundance concurrent with suppression within the spray zone.

Coincidental decreases in comparison and spray zone traps and red boxes were most marked at Breckenridge, even though comparison traps and red boxes were positioned in separate canyons and a previous dispersal study had indicated relatively moderate intercanyon movement (Milby et al. 1983). Declines in abundance at canyons A and C were attributed to the continuous loss of dispersives to canyon B, without replacement by emigrants from canyon B. Thus, recruitment was limited to emergence from breeding sites, most of which were located within the spray zone. In agreement, few mosquitoes released in canyon B were recaptured in canyons A and C after the first spray, while emigrants from A and C continued to be recaptured in canyon B. The consistent impact of adulticides on host-seeking females collected within 2.5, but not >4 km from settlement areas may begin to delineate the effective spatial distribution of *Cx. tarsalis* populations in nature.

ALTERATION OF HOST-SEEKING RHYTHM. The host-seeking rhythm of *Cx. tarsalis* females at John Dale was modified by adulticiding as indicated by a comparison of hourly time-segregated-sampler collections at Mosesian's and Costerisan's (Meyer et al. 1984). Prior to spraying at Mosesian's and during the spray period at Costerisan's, the peak collection of host-seeking females occurred 1–3 hr after sunset; however, during the spray period at Mosesian's the postsunset peak was attenuated. Meyer et al. (1984) attributed the change in the collection pattern to adulticides eliminating females resting at Mosesian's. The delay in the peak host-seeking period represented the additional time required for the mosquitoes to traverse the distance from unsprayed diurnal resting sites to the time-segregated-sampler.

INFLUENCE OF AUTOGENY ON PARITY DETERMINATION. Significant numerical suppressions at semi-isolated foothill sites were accompanied by significant decreases in parity. Changes in parity status were less detectable at the valley site where autogeny rates were elevated. Autogenous females delay host-seeking activity until after the initial oviposition and thus are not collected host-seeking at CO_2 traps until after they become parous (Nelson and Milby 1982). Decreases in parity were most marked during the postspray period and persisted among resting females up to 2 wk postspray at Poso West. The slow decline in the parity rate, despite the rapid decrease in numerical abundance, indicated the importance of repeated spraying in eliminating the older and potentially infected component of the population. The relative abundance and parity rate of host-seeking, and presumably more dispersive, females recovered more rapidly than did that of the resting population.

CONCLUSIONS

Experimental aerial sprays of foothill and valley habitats during the summers of 1982 (Reisen et al. 1984) and 1983 indicated that a marked suppression of *Cx. tarsalis* numerical abundance occurred when the target population was susceptible and exposed to the spray. Partial insecticide resistance to organophosphate and pyrethroid treatments during 1982 contributed to reductions in both the rate and level of population suppression (Reisen et al. 1984). Population suppression was more pronounced and longer-lasting at semi-isolated foothill sites where recruitment by immigration was limited. The reduction of the male population was always greater than for the more vagile females. Effective control of adults at diurnal settlement areas suppressed abundance within the spray zone and at comparison sites up to 2.5 km, but less than 4 km, distant from the boundary of the spray zone.

Marked decreases in parity rates occurred after propoxur adulticiding at foothill populations with low autogeny rates. Similar decreases in the insemination rate paralleled comparatively greater reductions in male abundance as indicated by significant changes in the sex ratio. Changes in parity rates were not observed in 1982 when chlorpyrifos sprays eliminated both susceptible immature and adult mosquitoes (Reisen et al. 1984). High autogeny rates at John Dale during both years precluded the use of the parity rate to detect changes in the age structure of the host-seeking population.

Significant decreases in *Cx. tarsalis* relative abundance attributable to adulticiding were accompanied by concurrent declines in WEE MIR's on 3 occasions at John Dale. However, the relative abundance of host-seeking females never declined to <30 females per CO_2 trap night and the WEE MIR remained > 1 per 1000. Transmission of WEE virus to sentinel chickens did not appear to be interrupted by adulticiding, although sentinel exposures were not limited specifically to prespray, spray and postspray periods. These data imply that focal aerial applications would provide only partial control in an epidemic situation in rural Kern County, California. Research on spray delivery systems, insecticide formulations and application schedules remain a research priority in the development of strategies for the management of mosquito-borne diseases in epidemic situations.

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