ture inversion) or warm air overhead would be optimum for aerosol and fine spray applications. But the proper height to fly along with the spray drop size to use in order to obtain optimum recovery and maximum swath width is not easily found and may as we suspect, vary greatly with the changing weather of early evening spraying.

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RICE FIELD MOSQUITO CONTROL STUDIES WITH LOW VOLUME DURSBAN® SPRAYS IN COLUSA COUNTY, CALIFORNIA. III. EFFECTS UPON THE TARGET ORGANISMS.

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An operational plan for alleviating the mosquito problem associated with rice culture in Colusa County, California, was described by Womeldorf and Whitesell (1972). The following report summarizes the effects of implementing this plan on field populations of the target organisms *Culex tarsalis* and *Anopheles freeborni*. Further evaluation of the low volume applications with caged mosquitoes is reported elsewhere (Akesson *et al.*, 1972).

PROCEDURE. The extent of rice culture within and outside of the treatment area (Mosquito Abatement District boundary) and the major communities that served as mosquito adult sampling sites are shown in Fig. 1. For operational purposes, the rice fields to be treated within the District were grouped into four subareas (A, B, C and D). Area A encompassed 4,585 acres of rice in the southwest portion of the District; Area B, 3,564 acres, northwest; Area C, 2,082 acres, southeast; Area D, 7,534 acres, northeast. Within each of the four sub-areas, 10 rice fields were inspected for mosquito larvae at weekly intervals for approximately 15 consecutive weeks from June through August or September when the fields were drained for harvesting. An inspection consisted of 15 dips with an enamel dipper at each permanent station. Six additional rice fields outside the treated area were also inspected weekly.

Four New Jersey light traps were operated 4 nights per week from April through September. Three traps were located within the city limits of Colusa, and the

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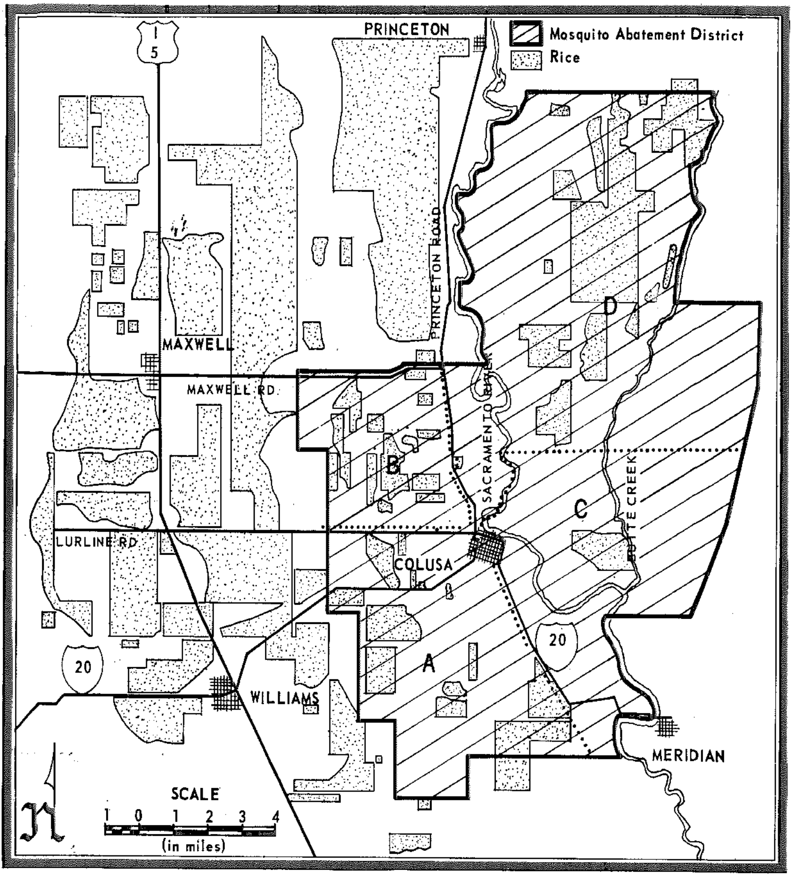

FIG. 1.—Study areas A, B, C and D, land devoted to rice and major communities in Colusa County, California.

fourth, approximately a mile southeast of the center of town.

In early July, 27 red boxes (one cubic-foot) were placed in various urban and rural situations throughout the county for pre- and post-treatment evaluation of the adult mosquito populations. From the original 27 boxes those in 18 locations were selected as permanent sampling sites. These locations included Williams (2), Maxwell (4), Princeton (2), Meridian-Grimes (3), Colusa-urban (3), and Colusa-rural (4) (see Fig. 1).

Adult mosquitoes were collected from these red boxes between 0630 and 1100 hours 4–5 days before and 12–14 days after the third application. Mosquitoes were aspirated from the red boxes, transferred to carton cages and transported to the laboratory where they were anesthetized, identified and sexed. Females were classified into categories of empty (no blood, no obvious egg development), blood engorged, or gravid. Ovaries from these females were dissected and examined to determine the extent of oogenesis and the level of parity.

RESULTS. The dates of the three low

TABLE 1.—Average number of C. *tarsalis* males and females per light trap night, by month, April–September, 1968–1970.

	Average no. *C. tarsalis* per trap night					
	Male			Female		
	1968	1969	1970	1968	1969	1970
April	0.2	0.0	0.1	0.3	0.0	0.0
May	0.1	0.0	0.0	1.0	0.4	0.2
June	1.9	0.2	0.1	19.8	2.8	7.4
July	2.8	0.1	1.8	20.5	9.2	17.3
August	2.0	0.0	1.9	28.0	10.5	8.6
September	1.1	0.3	3.4	12.1	6.7	7.0

volume applications in relation to the average number of mosquito larvae collected each week from each area, are summarized in Figs. 2 and 3.

In the first treatment, an overall (areas A, B, C and D) reduction of approximately 87 percent of the *C. tarsalis* larval population was observed. Following the second application, a reduction of 77 percent was observed, but the larval population in the area with the greatest density (B) did not decrease to the low levels achieved in areas A, C and D. During the same time interval, the population in the untreated area increased 59 percent. Pre- and post-treatment inspections of supplementary fields within the treated area showed no reduction in at least 3 of 9 fields.

A 93 percent reduction of the *A. freeborni* larval population was observed after the third treatment, while the population in the untreated fields during the same period increased 54 percent.

The average number of adult *C. tarsalis* and *A. freeborni* per light trap night by month for 1970 and for the two previous years with little or no control is shown in Tables 1 and 2. In comparison to 1968 and 1969, little or no reduction in either male or female *C. tarsalis* was observed in 1970. *A. freeborni* females in July and August were somewhat lower in 1970 than in 1968 or 1969.

The average number of *C. tarsalis* and *A. freeborni* adults per red box collection 4–5 days before and 12–14 days after the third application in rural communities within and outside the larvicidal area is presented in Table 3. Parity and percentage of *A. freeborni* females with follicular stage I–II are summarized in Table 4. The marked increase in the latter condition among the post-treatment individuals presumably indicated the onset of diapause in those females (Hitchcock, 1968; McKenna and Washino, 1970).

DISCUSSION. The strategy of the Colusa

TABLE 2.—Average number of *A. freeborni* males and females per light trap night, by month, April–September, 1968–1970.

	Average no. *A. freeborni* per trap night					
	Male			Female		
	1968	1969	1970	1968	1969	1970
April	0.0	0.0	0.0	0.3	0.1	0.1
May	0.0	0.0	0.0	0.1	0.2	0.0
June	0.0	0.0	0.0	2.3	3.0	3.3
July	0.0	0.0	0.0	26.5	53.5	14.9
August	3.0	0.6	0.4	110.0	40.2	30.7
September	7.9	1.5	8.7	35.5	2.6	15.9

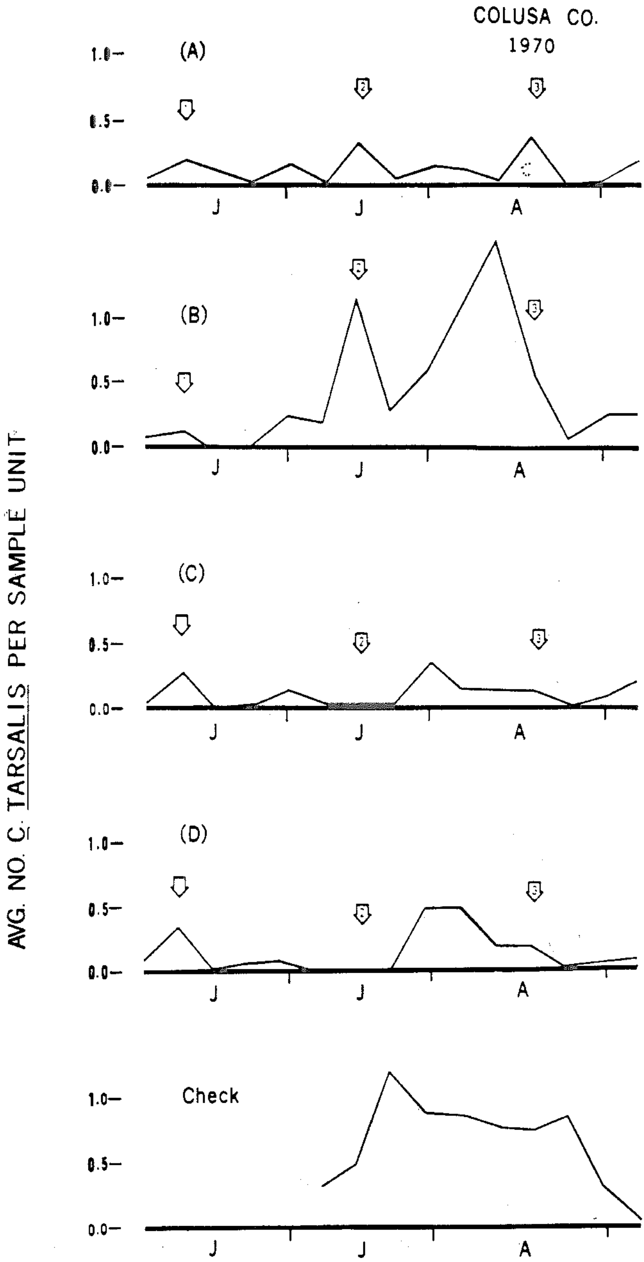

FIG. 2.—Average number of *C. tarsalis* larvae per sample unit (dip) from 46 rice fields in 4 treated and one check areas, and time of insecticide treatments.

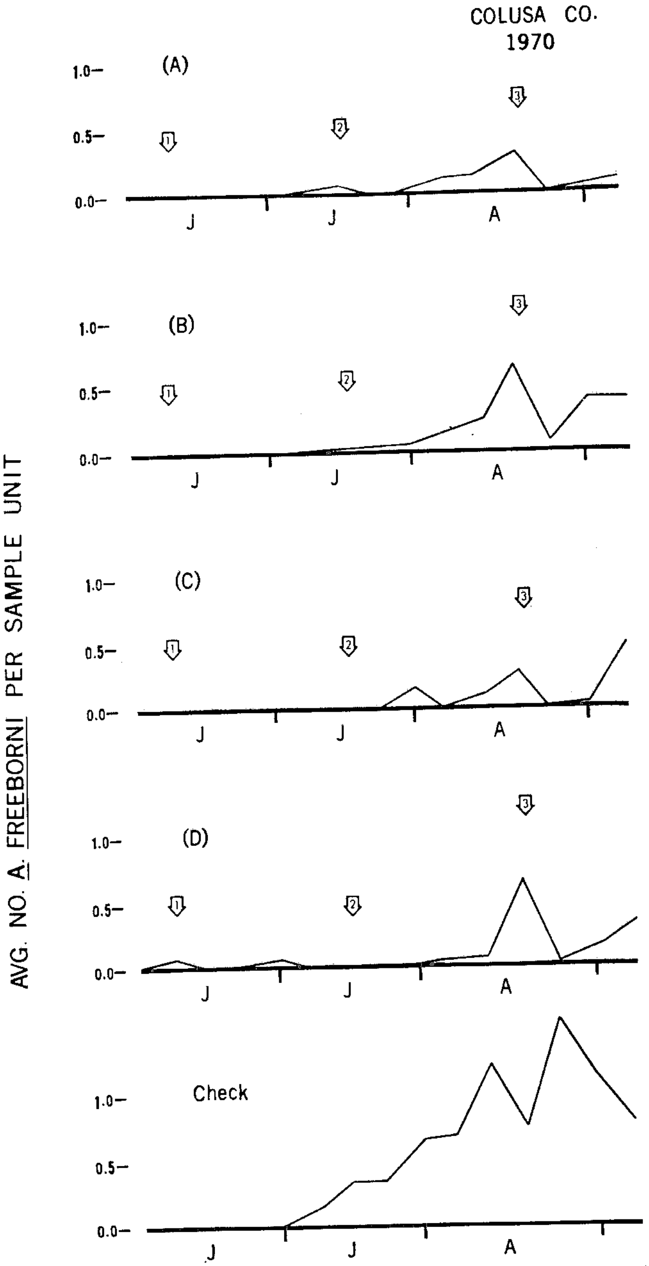

FIG. 3.—Average number of *A. freeborni* larvae per sample unit (dip) from 46 rice fields in 4 treated and one check areas, and time of insecticide treatments.

TABLE 3.—Average number of male and female *C. tarsalis* and *Anopheles freeborni* per red box collection 4–5 days before and 12–14 days after the third Dursban application in treated and nontreated areas.

		Culex tarsalis				*Anopheles freeborni*			
		Male		Female		Male		Female	
	Sampling Site	pre	post	pre	post	pre	post	pre	post
Area with no larviciding	Williams	1.0	0.5	3.0	2.0	22.5	19.5	102.0	77.0
	Maxwell	2.3	4.0	5.3	3.0	13.3	43.5	61.0	68.5
	Princeton	4.5	3.0	9.5	2.5	25.0	53.0	123.0	124.0
	Meridian-Grimes	6.3	0.0	14.3	1.7	5.0	19.7	17.0	58.0
Area with larviciding	Colusa (urban)	1.3	1.0	9.6	8.0	0.8	10.3	21.0	48.3
	Colusa (rural)	0.0	0.3	2.3	0.8	2.3	14.0	49.5	44.0

Mosquito Abatement District for controlling mosquitoes associated with rice fields was based on two factors previously discussed (Whitesell, 1968). First, inspection and control of rice fields in this county cannot be done economically on an individual field basis owing to the vastness of the area. Since adult mosquitoes had been observed to occur at nearly the same time each year in three well defined peaks, it was speculated that synchronizing area-wide applications with these peaks, instead of treating individual fields, might afford a better opportunity for success. Secondly, the savings in time and materials derived from the use of low volume technique would enable treatment of virtually the entire rice acreage, a task that had been economically infeasible by conventional means.

The extent of *C. tarsalis* reduction from the first two treatments in the present study (Fig. 2) was not as substantial as in the earlier studies (Burgoyne *et al.*, 1968), but this may be attributed partially to a more intensive sampling program in the present evaluation. Unfavorable wind conditions during the week of the second application and the possibility of using dosage levels inadequate to penetrate emerging rice stand caused considerable concern during the operation.

TABLE 4.—Parity and percentage of females with ovary stage I–II, *A. freeborni*, 4–5 days before and 12–14 days after the third Dursban application in treated and nontreated areas.

		Total no. examined		% empty & parous		% blooded & parous		% empty w/ov. I–II	
	Sampling Site	pre	post	pre	post	pre	post	pre	post
Area with no larviciding	Williams	80	76	22.5	30.0	45.0	38.9	22.5	60.0
	Maxwell	79	120	34.4	25.3	19.2	48.8	6.3	49.4
	Princeton	81	75	24.4	25.0	45.0	48.6	19.5	37.5
	Meridian-Grimes	40	61	13.6	8.2	33.3	50.0	33.3	67.4
Area with larviciding	Colusa (urban)	59	72	36.7	10.2	44.8	52.2	10.3	44.9
	Colusa (rural)	72	101	20.5	16.9	24.2	43.3	10.3	53.5

Substantiating this concern was the fact that *C. tarsalis* control in Area B was inferior to that of other areas after the first or second treatment. Also, a third of the pre- and post-treatment inspections of 9 supplementary fields within the treated area showed no reduction of mosquito larvae. The success of the second application was seen in the substantial overall reduction of the larval population. Furthermore, results of concurrent field tests confirmed the penetration of larvicidal material in sufficient quantity to kill virtually all of the test mosquito larvae in bioassay containers at the water level (Akesson *et al.*, 1972).

The increase of *C. tarsalis* in Area B during mid-August can possibly be attributed to a failure to reduce the population sufficiently to prevent rapid resurgence. The decision not to treat Area B in spite of the late season increase in *C. tarsalis* was in keeping with the original strategy of timing the third treatment with an increase in the anopheline larval population. The substantial reduction of the anopheline larval population indicated that the third treatment was probably a successful one.

In spite of an overall 87 percent and 77 percent reduction of the *C. tarsalis* larval population in the first two treatments, light trap indices showed little or no reduction in adult males or females in 1970 in comparison with 1968 and 1969. In addition, no reduction was observed in red box collections before and after the third treatment in the town of Colusa.

Following the third treatment in August, a 93 percent reduction of *A. freeborni* larvae was observed. Adult females collected in light traps during July and August were somewhat fewer in 1970 than in 1968 or 1969 (Table 2), but collections from red boxes before and after the third treatment did not confirm this decrease (Table 3). Differences in the parity rates of females before and after treatment as demonstrated in the successful ULV operation against *Aedes aegypti* (Lofgren *et al.*, 1970) were not observed for *A. freeborni* in our investigation.

The results of this study demonstrated the technologic and economic feasibility of treating all rice fields (approximately 20,000 acres) within a large area (160 sq. miles) over a short span of time (4–5 days) on three separate occasions to substantially reduce the mosquito larval population. However, most indices for adult mosquitoes did not exhibit a comparable reduction. The known flight range of the two mosquitoes (Dow *et al.*, 1965; Bailey *et al.*, 1965, 1967) and the extensive rice acreage outside the District (Fig. 1) led us to believe that adult females infiltrated the area from bordering untreated rice fields. Since wider dispersal is associated with the late summer-fall adult population (Bailey *et al.*, 1967), the high percentage of females in apparent diapause during post-treatment evaluation also supports the supposition that considerable infiltration had taken place.

Our conclusion regarding the program objective was that the larviciding with concentrated Dursban was successful. However, our inability to reduce the adult population substantially led us to believe that a more realistic objective of providing relief from adult mosquitoes for Colusa residents was not achieved. If these conclusions are accepted, efforts to obtain improved results in such situations cannot depend solely upon further improvement in larviciding technology. Genuinely successful operations will probably require a fully integrated program with the larviciding activities being augmented by habitat management and the use of adulticides when necessary. Otherwise, in any program where the control of larvae, through either biological and chemical means, serves as the primary effort, control areas must be sufficiently large to include most breeding situations. In Colusa County, the area under control should have been expanded to provide coverage of the approximately 60,000 rice acres outside of the district boundary.

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CALIFORNIA AND WESTERN ENCEPHALITIS VIRUSES FROM BONNEVILLE BASIN, UTAH IN 1965

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ABSTRACT. Mosquitoes, collected by aspirating from humans and by light traps at six sites in West Central Utah, were pooled by species and assayed for arboviruses. Ninety-nine percent of the isolates were from *Aedes dorsalis* which constituted 97 percent of the total 228,590 mosquitoes collected. Only 143 of the 559 isolates were specifically identified. There were 107 California Group isolates and 62 Western encephalitis isolates, but both viruses were found in each of 26 *A. dorsalis* pools. The abundance of *A. dorsalis* and arbovirus isolates may have been due to above normal precipitation in each of the months May through September 1965.

A qualitative survey of arboviruses of the Bonneville Basin of West Central Utah was made in 1965 to study the role of mosquitoes as possible vectors of Group A arboviruses. As previously indicated by Thorpe, Smart and Sidwell (1965), arbovirus complement fixing antibodies were found in the sera of animals of the area. Data are presented here on isolations of California Group and Western encephalitis viruses from indigenous mosquitoes. These isolations represent the first California Group isolates from the Bonneville Basin. Crane *et al.* (1970) reported 15 California Group isolates from mosquitoes collected in 1967 on the eastern side of the Bonneville Basin and Elbel *et al.* (1971) reported 49 California Group isolates from mosquitoes collected in 1966 and 1967 on the western side of the Basin.

AREA DESCRIPTION AND STUDY SITES

The physiography of the Bonneville Basin was described by Pack (1939).