FURTHER STUDIES ON THE CHEMICAL CONTROL OF RICE FIELD MOSQUITOES IN MISSISSIPPI [1, 2]

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INTRODUCTION. Preliminary investigations (Mathis, *et al.*, 1953) indicated that a preflood application of dieldrin emulsion at a rate of 1.0 pound of dieldrin per acre to rice fields in Mississippi gave excellent control of *Psorophora* larvae for an entire season. A similar treatment at a dosage rate of 0.5 pound of dieldrin per acre was highly effective during a 7-week period of observation. As these studies were confined to plots of 100 acres or less, an appraisal of the effect of the treatment upon adult mosquito populations was not feasible. In 1954 a large-scale test involving 2900 acres of rice in Bolivar County, Mississippi, was established to determine if satisfactory abatement of the adult population could be accomplished by this method of chemical control.

METHODS. The experimental area was selected to provide a heavy concentration of rice fields in the center zone with the latter being sufficiently removed from peripheral untreated rice acreages to minimize the infiltration of adults from the untreated fields. The treated rice fields approximated 2900 acres, of which 2700 acres were located within 6 miles of the center of the experimental area. This center point was 8 miles from any untreated rice fields, a distance which was considered beyond the general dispersion range of *Psorophora confinnis* (Quarterman, *et al.*, 1955; Horsfall, 1942).

All treated rice fields received a preflood application of dieldrin emulsion at a rate of 0.5 pound of dieldrin per acre. Treatment was made with a PT-17 airplane equipped with Venturi-type nozzles. Spray operations began on April 27 and extended through June 21, but the major part of the acreage (2100 acres) was treated before May 8. Some fields were flooded partially at the time of treatment, whereas with others 1 to 5 weeks elapsed before inundation.

An index to the larval population of *Psorophora* was obtained by the use of a cone sampler which covered an area of 0.5 square foot. Only fields which had been flooded recently were sampled. When early instar larvae were detected in a field, sampling was continued for several days to determine the number of larvae that reached maturity.

Appraisal of the adult mosquito populations was accomplished by the use of New Jersey light traps. Forty traps were operated twice each week during the experimental period. For proper distribution of the traps, the experimental area was divided into five zones in relation to the distance from the center of the treated area (figure 1). The code designations and distances involved were as follows: A Zone—0 to 2.9 miles, B Zone—3 to 5.9 miles, C Zone—6 to 8.9 miles, D Zone—9 miles, X Zone—greater than 9 miles.

The approximate location of the individual traps is given in figure 1. At farmhouses near the treated fields, one trap was located per each 200 acres of treated rice. The traps placed in outer zones (B, C, D,) also were operated at farmhouses, but the sites were selected to reflect any marked migration of mosquitoes into the treated zones from the untreated areas. In the X Zone the traps were located at houses near untreated rice fields.

RESULTS. Routine sampling of rice fields treated prior to June 1 failed to reveal any *Psorophora* larvae until 4 weeks following treatment. During this same period, *Psorophora* larvae were present in recently flooded untreated ditches and abandoned fields. However, by the sixth

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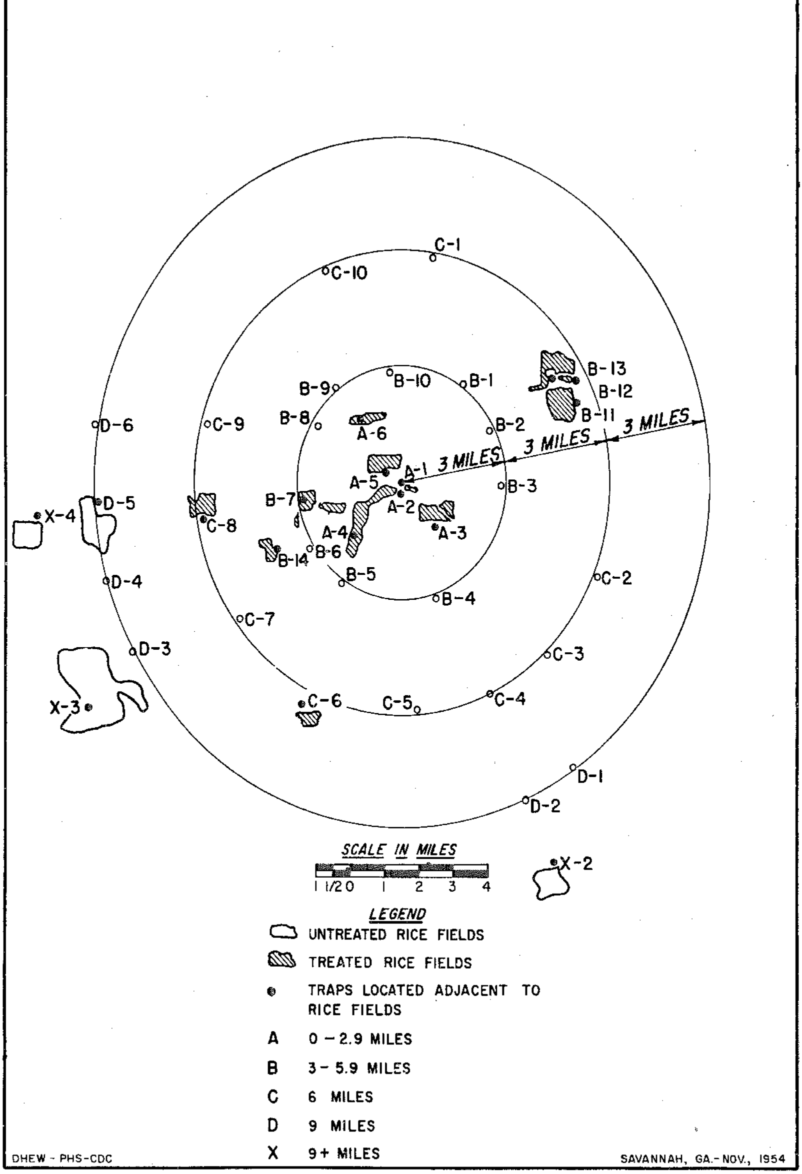
FIGURE 1

DISTRIBUTION OF LIGHT TRAPS IN EXPERIMENTAL AREA



and seventh posttreatment week mature *Psorophora* larvae were numerous in reflooded fields. Two fields treated on June 14 and 21 and flooded within 10 days contained numerous larvae which were able to complete their development. In general, it appeared that fields which were flooded or reflooded later in the season showed the greatest initial larval population and also the maximum number of larvae surviving the treatment.

Adult population trends of *Psorophora confinnis* and *P. discolor* as measured by light trap collections are given in table 1.

TABLE 1.—The numbers of adult *Psorophora confinnis* and *P. discolor* collected in light traps within Zone A of treated area and the numbers collected in the untreated area (Zone X)

	Psorophora confinnis		*Psorophora discolor*	
Week	Ratio A to X	Average No. specimens per trap in X	Ratio A to X	Average No. specimens per trap in X
May 17	1–45	81	1–3	51
24	1–37	205	1–3	469
31	1–41	742	1–1	222
June 7	1–49	885	1–3	349
14	1–85	761	1–2	206
21	1–20	7,328	1–1	1,996
28	1–18	15,356	1–2	3,148
July 5	1–5	20,954	2–1	1,312
12	1–2	3,984	2–1	377
19	3–1	6,346	3–1	1,058
26	1–2	4,489	1–1	561
Aug. 2	1–5	4,301	1–6	1,303
9	1–4	440	1–3	35
16	1–4	583	1–14	337
23	1–2	1,081	1–1	28
30	1–2	302	3–1	10
Sept. 6	4–1	431	1–1	9

Excellent control of *P. confinnis* was apparent through the week of June 28. After that period the treatment was not considered effective.

In contrast to the excellent short-term abatement of *P. confinnis*, satisfactory control of *Psorophora discolor* never was obtained. In 8 of the 17 weeks, the average number of *P. discolor* per collection in the treated area was equal to, or greater than, that in the untreated area. Likewise, *Anopheles quadrimaculatus* was not under control at any time. While neither *P. discolor* nor *A. quadrimaculatus* is a serious daytime pest in the area, both are annoying nighttime biters.

As indicated by the average number of adult mosquitoes collected in the untreated zone in table 1, peak indices of *P. confinnis* prevailed during the 2-week period from June 28 through July 11. As in previous years, the population levels dropped markedly after the first week in August with subsequent densities being of a relatively low order. *P. discolor* reached maximum densities in late June but never displayed prevalences approaching those of *P. confinnis*.

Table 2 gives the percentages of the various species collected in the light traps in the different zones from May 17 to September 6. The predominant species collected was *Psorophora confinnis*, ranging from 52 to 84 percent. The highest percentage was noted in the *X* zone, the lowest in the *B* zone. *P. discolor* was the second most numerous species collected, ranging from 14 (*X* zone) to 44 (*B* zone) percent. In view of its scarcity in 1952–53, the relatively high incidence of *P. discolor* in the 1954 collections is puzzling. *Anopheles quadrimaculatus* constituted less than 4 percent of the specimens taken in any zone and all other species combined made up less than 1 percent of the total mosquitoes recovered. The two species of *Psorophora* represented 96 to 98 percent of the total specimens collected. The percentage of each species in the *X* zone undoubtedly was more representative of the true ratio of the mosquito populations near rice fields.

Although many of the earlier treatments were made under adverse weather conditions, this was not a reason for the failure of the treatment, since fields treated under ideal weather conditions also pro-

TABLE 2.—Percentages and numbers of indicated species of mosquitoes collected in light traps by zones from May 17 to September 6, 1954, Cleveland, Mississippi

	Zone A	Zone B	Zone C	Zone D	Zone X
Total number of mosquitoes	348,796	331,123	237,372	183,292	503,468
Psorophora confinnis	66.4	51.9	69.0	71.8	83.8
Psorophora discolor	29.4	44.3	28.3	25.3	13.6
Anopheles quadrimaculatus	3.7	3.4	2.1	2.4	1.6
Other spp.	0.5	0.4	0.6	0.5	1.0

duced unsatisfactory results. Moreover, the poor results obtained 10 days after treatment of fields gave no grounds for assuming that the extended periods between the initial and second flooding were the cause of failure.

To determine if a higher dosage of dieldrin per acre would have attained effective results, a series of small plots (15′×25′) were treated during July with dieldrin emulsion at the rates of 0.5, 1, and 2 pounds of dieldrin per acre as a preflood treatment. When these plots were flooded less than 1 week later, unsatisfactory control was apparent. In addition, three plots were flooded and the dieldrin emulsion applied as a postflood treatment at the rate of 0.1 pound per acre. The larval mortality varied but the average kill was less than 50 percent 24 hours after treatment.

During July, bentonite pellets containing 5 percent dieldrin were hand broadcast to an 0.75-acre plot in a field which had previously been treated with dieldrin emulsion at the rate of 0.5 pound of dieldrin per acre. The pellets were applied at the rate of 2 pounds per acre (0.1 pound of dieldrin per acre). Larval counts made 24 and 48 hours after flooding indicated an 87 percent reduction but this was not considered satisfactory since an average of 85 *Psorophora* larvae per square foot existed on the 48-hour check.

A 50-acre field previously treated with dieldrin emulsion also received a treatment of dieldrin impregnated bentonite pellets at the rate of 0.2 pound of dieldrin per acre. In the heavy population of larvae present, a 78-percent reduction in density was obtained 48 hours after treatment. Again the treatment was unsatisfactory since the last inspection revealed an average of 36 larvae per square foot. These poor results could be ascribed in part to the coverage of the field obtained by the airplane treatment.

The failure of fresh residues of dieldrin to kill *Psorophora* larvae indicated the possible occurrence of resistance in *Psorophora* populations. To evaluate this premise, *P. confinnis* pupae were collected in August from fields treated with dieldrin and from fields and flooded pastures which had not been treated. The adults obtained were held from 1.5 to 3 days and then exposed to dieldrin- or DDT-treated paper, using a method similar to that of Fay, *et al.* (1953). Sheets of mimeograph paper were dipped either in a 0.25 percent dieldrin-xylene solution, a 1 percent dieldrin-xylene solution, or in a 1 percent DDT-xylene solution and then removed, the excess solution being allowed to drain off. Following this, the sheets were placed on a rack until dry.

Twenty female *P. confinnis* adults then were placed in cardboard cylinders lined with the treated paper for 45 minutes, removed to untreated cages, offered food and water, and held for a 24-hour mortality count. With each series of tests a set of untreated controls were run.

The results showed that the mortality of females from dieldrin-treated fields ranged from 6 to 52 percent when exposed to paper treated with 0.25-percent dieldrin solution (Table 3). The average adjusted 24-hour mortality for these females was 17 percent. With adults from untreated fields the range in mortality was from 67 to 100 percent. There was a difference of 70 percent between the adjusted average 24-hour mortalities of the females from treated and from untreated fields. When the strength of the dipping solution of dieldrin was increased to 1 percent, the mortality ranged from 10 to 44 percent with an adjusted mortality of 22 percent.

TABLE 3.—Average 24-hour percent mortalities of *Psorophora confinnis* females from dieldrin treated and untreated rice fields, when exposed to dieldrin or DDT residues obtained by immersion of paper in xylene-toxicant solutions of several strengths as indicated

Treatment of paper	Total no. females	No. replicates	Adjusted 24-hour mortality percentages*
Females from Treated Fields			
Dieldrin—0.25%	603	33	17
DDT—1.0%	451	24	83
Check—	488	25	8
Dieldrin—1.0%	989	50	22
Check—	517	25	3
Females from Untreated Fields			
Dieldrin—0.25%	711	37	87
DDT—1.0%	628	32	66
Check—	519	26	17**

* Percentages derived by Abbott's formula.
** Possibly due to accidental insecticidal contamination of holding cages.

With DDT-treated paper, the range in mortality was from 62 to 100 percent with specimens from treated fields and from 26 to 100 percent with those from untreated fields. The adjusted mortality for mosquitoes from the treated fields was 83 percent and 66 percent for those from the untreated fields. This low mortality of the females from the untreated fields was due to the results obtained with specimens from one particular site. The average mortality from this location was 64 percent as compared to 83 percent from the other three locations.

DISSCUSSION. The principal finding from these experiments is the demonstration of resistance to dieldrin residues in adult *P. confinnis*. Under the circumstances, it is difficult to ascribe this resistance to the 1954 dieldrin treatment of rice fields alone. Since the resident population of *P. confinnis* had been exposed to chemicals commonly employed for crop dusting (including endrin, aldrin, and dieldrin), it is assumed that this species was predisposed to a loss in susceptibility to dieldrin. Thus the complete treatment of all rice fields within a 6 mile radius by subjecting the population to intensive selection pressure caused a marked rise in its level of resistance to dieldrin. That such did not occur in fields treated in 1952 and 1953 is considered to be the result of the small and noncontiguous areas treated, a factor which permitted any resistance element of the *Psorophora* population to be diluted by the less resistant and dominant portion of the population.

The adult population indices in 1954 again support the previous assumption that only a small brood of mosquitoes is produced by overwintering eggs. They likewise implicate the cultural watering practices for rice growing as the major factor responsible for the copious *Psorophora* populations from June through early August.

As a further increment to the difficulty of the control problem, irrigation practices in Bolivar County are now being extended to pastures and to crops other than rice. With this enlargement of potential mosquito breeding area, control measures for *Psorophora* likewise require not only extension but adaptation to use under these conditions.

SUMMARY. Preflood airplane treatment of 2900 acres of rice fields in Bolivar County, Mississippi, in 1954, with dieldrin emulsion applied at a rate of 0.5 pound of dieldrin per acre failed to provide effective control of *Psorophora* breeding despite successful results with the same treatment in 1953. Plot tests showed dosages up to 2.0 pounds of dieldrin per acre to be ineffective against *Psorophora* breeding. Resistance studies with adult female *P. confinnis* demonstrated that in the treated area this species had acquired a marked resistance to dieldrin residues.

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CULICOIDES OF NEW ENGLAND (DIPTERA: HELEIDAE)

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The *Culicoides* have been the subject of an excellent study recently published by Foote and Pratt (1954). However, the present authors have additional material, much of which was collected during a two-year survey for the Communicable Disease Center, U. S. Public Health Service. This material is of interest particularly from the standpoint of increasing knowledge of the distribution of the group throughout New England. In addition, other material has been incorporated and verified, particularly that of the C. W. Johnson collection at Boston University which was not examined by Foote and Pratt nor included in their report. Previous records of all species, with complete data if the specimens have been examined, are also given. Notes on the biology of some of the species are included.

Most of the identifications have been made by or verified by the second author. Acknowledgements are due Frank R. Lisciotto and John C. Kuschke for their part in the collection of data. An asterisk indicates a new record for the state. Initials given in the collection records refer to: (EIC)—E. I. Coher, collector; (CWJ)—C. W. Johnson, collector; (HK)—H. Knutson, collector; (JCK)—J. C. Kuschke, collector; (FRL)—F. R. Lisciotto, collector; (MFS)—Maine Forest Service collection; (F & P)—in Foote and Pratt, 1954, see references; (OAJ)—in Johannsen, 1952, see references.

Culicoides biguttatus (Coquillet). ***Maine:** Ashland, VII-29-51(MFS); Dennistown, VII-21(JCK), VII-22, VII-25-51 (MFS); Greenville, VIII-1-51(MFS); Moosehorn, VII-3, VII-4, VII-6-51(MFS); Oxbow, VII-29-51(MFS); Square Lake, VII-8, VII-26-51(MFS); Vasselboro, VII-15-52(JCK). Extreme dates: VII-3 to VIII-1. **Vermont:** Laurel Lake, (F & P); Middlebury, VII-12(CWJ). **Massachusetts:** Amherst, (F & P); VI-19, VII-3, VIII-2, VIII-8 to 10, IX-10-51(EIC), light trap; Merrimacport, VI-11 to 16, VI-24, VI-25, VI-29, VI-30-54(EIC), hundreds in light trap except for final date; Sunderland, VII-12-51(EIC), light trap; Westhampton, VI-28-51(EIC), biting at 8:30 p.m.; Wilmington, (F & P). Extreme dates: VI-11 to IX-10. **Connecticut:** East Haddam, (OAJ); New Haven, VI-6-04(B.H. Walden); South Norwalk, V-30-43(M.E. Smith).

Culicoides canithorax Hoffman. **Maine:** Narrows, Mt. Desert, VIII-13-30(CWJ); South Harpswell, (F & P). **Massachusetts:** Cataumet, (F & P); Cranberry Bog, East Sandwich, VII-9-39(R.L. Armstrong); Mystic, East Sandwich, VI-22-39 (R.L. Armstrong); Essex Co.,(CWJ); Groton, (F & P); Hyannisport, VII-4-04; Woods Hole, VII-23-03(CWJ). ***Rhode Island:** Peacedale, VI-28-52(HK), biting.

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