ARTICLES

AIRPLANE SPRAYING WITH DDT FOR CONTROL OF SALT-MARSH MOSQUITO LARVAE[1]

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Enormous broods of the salt-marsh mosquitoes *Aedes sollicitans* (Walk.) and *A. taeniorhynchus* (Wied.) are produced each summer on the marshes just back of the outer protecting sand dunes along the coast of the Southeastern States. The Florida east coast between St. Augustine and Fort Pierce contains typical areas of marsh and was selected for experimental study in 1945. These marshes are covered primarily with pickleweed *(Saltwort)* and spike-grass *(Juncus)*, although some areas are heavily matted with salt grass *(Distichlis)* and black mangrove. The areas of mangrove are limited to the slightly higher edges of the marsh, and in this locality the tree is low-growing and bushy. Extensive series of ditches have been constructed to drain the water from the worst of the known breeding areas, especially within 10 miles of large towns.

As is the case with other species of mosquitoes that breed in floodwater, the stimulus for the hatching of salt-marsh mosquito eggs is flooding and attendant favorable temperatures. Owing to the sanding up of inlets in this area, the marshes are only slightly affected by tidewater, the principal cause of flooding being the seasonal rains from June through September. Extremely high tides combined with heavy rains occasionally induce breeding in unexpected places. Such situations call for the development of control measures which can be quickly applied to large areas.

Soon after DDT had been found to be an excellent mosquito larvicide (Deonier *et al.* 1945b), and spraying techniques for airplane application had been devised (Deonier and Burrell 1945a, Wisecup *et al.* 1945a), an attempt was made to develop procedures and dosages for abating the nuisance of salt-marsh mosquitoes by controlling the larvae in the breeding areas. Previous work had shown that adults of these species could be reduced by spraying DDT from an airplane (Lindquist *et al.* 1945), but such treatment, while spectacular and undoubtedly effective, required the spraying of many square miles of territory to control the adults which had emerged from a much smaller acreage of breeding area.

Two series of tests utilizing airplane application of sprays were conducted during the spring and summer. In the first series an attempt was made to secure control with applications made before flooding and hatching, and in the second series with direct larvicidal applications to typical marsh areas in which active breeding was occurring.

PREFLOODING APPLICATIONS

The success of preflooding applications of DDT sprays for the control of floodwater species of the *Psorophora* group had been demonstrated in 1944 (Wisecup and Deonier 1945b; Wisecup *et al.* 1945a).

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Similar treatments with 5 and 10 per cent of DDT were made at monthly intervals to a group of marshy islands in the Mosquito Lagoon south of New Smyrna, Fla., from April to June, 1945. These applications were made from a helicopter (HNS-1)[3] and an L-4 (Piper Cub) plane. It was hoped that sufficient DDT would be deposited to act as a larvicidal agent when flooding and subsequent hatching did occur.

Occasional sets of sod samples were taken at random from the treated islands and tested against laboratory-reared larvae of *Aedes aegypti* (L.), with the results shown in Table 1. Only limited breeding occurred on these islands during the initial flooding of late June; therefore, no data were obtained on the effectiveness of the treatments against salt-marsh mosquito larvae. Later flooding in August produced a tremendous crop of mosquitoes on all treated areas. It would appear that, under the Florida coastal conditions of intense sunlight and high humidity with heavy dews, the value of a DDT spray applied as a preflooding treatment is probably limited to a month.

TABLE 1. Toxicity to mosquitoes of DDT sprays applied by airplane to marshy islands before flooding occurred.

Date treated	Concentration of DDT	Type of spray	Dosage of DDT	Mortality of *Aedes aegypti* exposed to sod samples taken on—		
				May 17	May 29	June 13
	Per cent		*Pounds per acre*	*Per cent*	*Per cent*	*Per cent*
		Helicopter				
April 13	5	Fuel-oil solution	0.2	90	5	2
	5	Aqueous emulsion	.2	70	10	10
		Piper Cub				
May 8	5	Fuel-oil solution	.2	100	..	5
		Aqueous emulsion	.2	85	..	2
22	10	Fuel-oil solution	.4	..	75	0
		Aqueous emulsion	.4	..	60	5
			.8	..	100	45
		Check (untreated)		0	0	0

DIRECT LARVICIDAL APPLICATIONS

DDT larvicides were applied at the beginning of the rainy season, late in June, and thereafter with each brood of mosquitoes. Applications were made from a Stearman PT-17 biplane and an L-4 plane, both equipped with a supply tank, a wind-driven propeller pump, and outlet bars beneath the wings which were provided with either 60- or 70-gage outlet orifices. All applications were made by flying just above the low-growing vegetation.

The treatments used and the results obtained are presented in Table 2. The degree of control varied from perfect (no surviving larvae) to as low as 80 per cent when both oil solutions and water emulsions were used. It was apparent that 0.2 pound of DDT per acre was a minimum effective dosage, and that the type and amount of vegetation and the weather were important factors in determining the control obtained.

[3] This spraying was conducted on a cooperative basis by the Navy, the Coast Guard, and the Bureau of Entomology and Plant Quarantine.

TABLE 2. Control of salt-marsh mosquito larvae with DDT sprays applied by airplane, 1945.

Date treated	Concentration of DDT	Type of spray	Dosage of DDT	Area treated	Weather conditions	Average larvae before treatment	Control	Remarks
	Per cent		*Pounds per acre*	*Acres*		*Number*	*Per cent*	
		Stearman (PT-17) airplane equipped with breaker bars and spray booms having 70-gage orifices						
June 27	5	Fuel-oil solution	0.2	90	Hot, strong breeze	25	None	Equipment clogged
Aug. 31	5	Aqueous emulsion	.2	30	Warm, slight breeze	3	99.9	Open marsh, light vegetation
		80–20 fuel-lube oil solution	.2	30	Warm, slight breeze	3	98.4	
		Stearman (PT-17) airplane equipped with spray booms (no breaker bars) having 60-gage orifices						
Sept. 11	10	Aqueous emulsion	.8	15	Cool, slight drizzle	35	90	Application made after pupation had commenced
19	5	80–20 fuel-lube oil solution	.2	60	Warm, fair breeze	15	95	Series of open pools among sand dunes; poor drift of spray
19	10	Aqueous emulsion	.4	60	Warm, fair breeze	50	100	Perfect control in grassy sloughs
		Piper Cub (L-4) airplane equipped with breaker bars and spray booms having 60-gage orifices						
July 14	5	Fuel-oil solution	.2 [1]	10	Warm, little breeze	50	80	Perfect control in open water, none in areas of heavy vegetation
		Aqueous emulsion	.2 [1]	5	Warm, little breeze	100	80	
Aug. 11	5	Fuel-oil solution	.4 [2]	25	Cool, cloudy, slight breeze	15	99.8	Perfect control, except in one area of tall spike grass
29	5	Aqueous emulsion	.4 [2]	15	Cool, cloudy, fair breeze	100	100	¼ inch rain within an hour washed all residue into water
	10	Aqueous emulsion	.4 [1]	30	Cool, cloudy, fair breeze	15	100	¼ inch rain within an hour washed all residue into water
	5	80–20 fuel-lube oil solution	.4 [2]	15	Cool, cloudy, fair breeze	31	100	
	10	80–20 fuel-lube oil solution	.4 [1]	30	Cool, cloudy, fair breeze	50	100	

[1] 80-foot swath width.
[2] 40-foot swath width.

The spray booms initially designed for the Stearman (PT-17) airplane had outlets of only 70-gage size. This equipment delivered a spray in which nearly 65 per cent of the droplets had a diameter of less than 100 microns. This spray drifted widely and settled poorly under unfavorable weather conditions. The first larvicidal test with this equipment on June 27 was unsuccessful because the orifices became clogged. Tests with the equipment working properly on August 31 gave nearly perfect control.

When the size of the outlet orifices was changed to 60 gage and the impinging bars were removed, the droplets were larger and tended to fall in a more even swath. The application with this equipment on September 11 was made after pupation had commenced, and despite the heavy dosage a fair brood of adults emerged. The tests of September 19 were conducted on areas which were not typical open marshes. The application of 0.4 pound of DDT per acre as a 10-per cent aqueous emulsion gave perfect control in a series of grassy sloughs. Less effective control was obtained with 0.2 pound of DDT per acre as a 5-per cent oil solution over open pools among the seaside dunes, where a high lapse rate (uprising air) and a strong wind resulted in poor deposition.

The Piper Cub, which was equipped with breaker bars and spray booms having 60-gage orifices, produced a spray with a wide range of droplet diameters. This airplane appeared to exert much less downward thrust to the spray than did the Stearman. Unsatisfactory control was secured on July 14 with a solution and an emulsion, each containing 5 per cent of DDT, applied at the rate of 0.2 pound of DDT per acre. The plane was flown over swaths 80 feet wide and the spray did not penetrate the thick vegetation. On August 11 nearly perfect control with the solution was obtained in a marshy area similar to the one treated on July 14 by decreasing the swath width from 80 feet to 40 feet and thus applying 0.4 pound of DDT per acre.

The tests on August 29 were designed to compare the control obtained with solutions and an emulsion applied to swaths 40 and 80 feet wide. A heavy shower immediately after the final treatment washed sufficient material from the vegetative cover into the water to cause complete mortality in all plots. Further replications were prevented by the transfer of this airplane to another project.

DEPOSITION AND PENETRATION STUDY

A single 15-acre marsh area was treated with 5 per cent of DDT in an oil solution which contained an oil-soluble dye, in order to study the deposition and penetration of the spray. Glass plates and slides coated with magnesium oxide were exposed at 10 random locations, both above and below the vegetative cover. The spraying was done with a Piper Cub airplane calibrated to discharge 4 quarts of oil per acre when flying swaths 40 feet wide. This should have deposited 0.4 pound of DDT per acre. The results were determined by colorimetric analyses of the residues on the plates and by microscopic examination of the slides, and are presented in Table 3. The deposition of DDT on the exposed plates ranged from 0.22 to 0.82 pound, with an average of 0.43 pound, per acre. This variation shows that even with a narrow swath the DDT deposit was very irregular. The amounts of DDT on the hidden plates varied according to the protection they received. The degree of penetration ranged from 2 to 100 per cent, 0.1 pound of DDT per acre being the smallest amount deposited. In general, the proportion of different-sized drops that penetrated the foliage was the same as for those deposited on the exposed plates.

Discussion.—Treatments applied before the flooding of known breeding areas were of no value in the control of *Aedes* larvae during 1945. Such treatments of most marsh areas would be of doubtful value, for the following reasons: (1) The time between treatment and flooding is dependent upon climatic conditions, and

TABLE 3. Deposition and penetration of DDT-oil spray applied to salt-marsh area by airplane

Station	Cover	Location of plates with respect to vegetative cover	Dosage of DDT	Droplets in indicated range		
				10–100 microns	100–220 microns	220+ microns
			Pounds per acre	*Per cent*	*Per cent*	*Per cent*
1	Slight; short grasses	Above	0.44	41	30	29
	Thin stand	Below	.46	36	31	33
2	Fair; short pickleweed	Above	.24	59	37	7
	Thin stand	Below	.12	67	28	5
3	Fair; short pickleweed	Above	.45	37	44	19
	Thin stand of spikegrass	Below	.26	39	41	20
4	Good, short pickleweed	Above	.46	54	21	25
	Thick stand	Below	Spoiled	26	38	36
5	Very good; tall pickleweed	Above	.22	57	38	5
	Thin stand of spikegrass	Below	.03	69	26	5
6	Fair; tall pickleweed	Above	.53	58	33	9
	Thin stand	Below	.12	59	32	9
7	Good; spikegrass	Above	.82	30	42	28
	Compact stand	Below	.11		Spoiled	
8	Fair; short pickleweed	Above	.34	45	36	19
	Medium stand	Below	.23	50	29	21
9	Good; medium pickleweed	Above	.30	49	43	8
	Thick stand	Below	.15	62	10	28
10	Excellent; tall pickleweed	Above	.46	33	32	35
	Tall spikegrass	Below	.91	45	51	4
	Average	Above	.43	46	35	19
		Below	.17	50	32	18

may be several months, (2) the intervening weather is deleterious to the applied spray, and (3) the flooding is frequently so heavy that the toxic residue might be washed away.

There were indications that the sprays were screened out less by low, thick cover than by tall, thin stands of vegetation. Tall growth especially impeded the deposition of drifting spray. There appeared to be less contamination in areas of tall spikegrass than in areas of low growing, relatively dense pickleweed. It is probable that sufficient DDT was deposited to give control of *Aedes* larvae at all stations except numbers 5 and 10.

Summary.—Large-scale applications of DDT sprays from airplanes as preflooding treatments gave no control of salt-marsh mosquito larvae in 1945.

Direct application of DDT sprays by airplanes is a feasible method of controlling salt-marsh mosquito larvae. The treatments must be applied before pupation commences, and sufficient material should be applied so that it penetrates the vegetative cover. A minimum effective dosage was 0.2 pound of DDT per acre. More satisfactory control was secured from the application of 0.4 pound of DDT per acre. At this dosage a sufficient amount of DDT to control *Aedes* larvae penetrated all except the tallest and densest vegetation.

Literature Cited

DEONIER, C. C., AND R. W. BURRELL. 1945a. Airplane application of DDT larvicides. Jour. Econ. Ent. 38(4):425–427.

DEONIER, C. C., R. W. BURRELL, J. D. MAPLE, AND J. H. COCHRAN. 1945b. DDT as an anopheline larvicide: preliminary field studies. Jour. Econ. Ent. 38(2):244–249.

LINDQUIST, A. W., A. H. MADDEN, C. N. HUSMAN, AND B. V. TRAVIS. 1945. Dispersion of DDT from airplanes for control of adult mosquitoes. Jour. Econ. Ent. 38(5):541–544.

WISECUP, C. B., W. C. BROTHERS, AND P. M. EIDE. 1945a. Airplane spraying of rice fields with DDT for control of mosquito larvae. Jour. Econ. Ent. 38(6):686–688.

WISECUP, C. B., AND C. C. DEONIER. 1945b. DDT for the control of *Psorophora* mosquitoes. Jour. Econ. Ent. 38(2):250–252.