technicians and sub-professional personnel. Considerable emphasis by all three services has been placed on vector control training programs and, as we have mentioned the annual two weeks of active duty "for training" keeps the Reserves in up-to-the minute touch with our military program—and we with theirs.

SUMMARY. We have attempted to describe the interactions between the military control and the civilian mosquito abatement which we feel are mutually valuable. Where the military need for control is not matched by a need on the part of the surrounding community, we augment such control either with our own forces or by contract with civilian agencies. Where there are strong programs on both sides of the fence, we lend support to the civilian efforts by the indoctrination and training of our personnel who live, or will live, in communities and provide a growing body of support to mosquito abatement. By grants to research, the military aid in the discovery of materials, techniques and equipment which will improve the efficacy of efforts by all agencies. And by participation in civilian conferences and the temporary resorption into our ranks of civilian mosquito workers who are Reservists, we help to speed up the flow rate at which information on practical control techniques passes around. We feel that at least some of the generally increasing interest among the populace in genuine mosquito control is due to the example of the military programs which are on view around the world. We also feel that the military and the civil programs are too closely interwoven to be successfully separated and we hope it continues to be that way.

PRESENT STATUS OF INSECTICIDES FOR MOSQUITO CONTROL IN FLORIDA

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In Florida, insecticides are used extensively for the control of *Aedes taeniorhynchus, Aedes sollicitans, Culex quinquefasciatus, Culex nigripalpus,* and *Psorophora confinnis;* and to a lesser extent against *Aedes aegypti, Mansonia* spp., fresh-water *Aedes* and *Anopheles* spp.

With the intensive research on arboviruses now being conducted in the state, it is not possible to say what other species might be added to the list for serious attention by control districts in the near future. New information already has justified second thoughts about some of the fresh-water *Aedes* and at least one anopheline. Reliable information on the present status of insecticides against certain of these species is fairly complete; for others it is, at best, sketchy or incomplete.

CHLORINATED HYDROCARBONS. *Aedes taeniorhynchus* and *Ae. sollicitans* present a single problem from the standpoint of control, with *taeniorhynchus* being by far the dominant salt-marsh species over most of the state.

It was against these species that the armed forces during World War II, and the mosquito control districts in the immediate post-war period, demonstrated that mosquitoes could be controlled over large areas with DDT applied by aircraft as a larvicide—adulticide. However, by 1949 DDT resistance was demonstrated in several counties (Deonier and Gilbert 1950; Bertholf 1950; Cain 1950; King 1950). There followed a short period during which other chlorinated hydrocarbons were used with varying degrees of success (Keller and McDuffie 1951; Keller and Chapman 1953).

However, by 1955 a number of Florida

[1] Contribution No. 139 Entomological Research Center.

mosquito control districts were reporting failures with BHC and dieldrin, the most widely used substitutes for DDT (Beidler, 1956; Bertholf 1956; Stutz 1956; Thomas 1956; Wenner 1957). Warner (1956) reported generally poor results from tests with thermal aerosols containing BHC and DDT against salt-marsh *Aedes* in the Florida Keys, and McWilliams and Munn (1957) reported that larvae of salt-marsh *Aedes* collected near the U. S. Naval Base at Key West were resistant to DDT, lindane, and dieldrin. Tests conducted at the Entomological Research Center in 1957 with DDT aerosols against *Ae. taeniorhynchus* from seven widely separated areas of the state confirmed that DDT resistance was general throughout the salt-marsh areas of Florida (Rogers and Rathburn, 1958).

Although most of the districts had discontinued the use of chlorinated hydrocarbons by 1955, resistance has persisted during the past 9 years. Davis *et al.* (1959) reported that larvae of salt-marsh *Aedes* from Florida were 8 to 10 times more resistant to DDT, BHC, and dieldrin than larvae from Georgia and that there was no more than a two-fold difference in susceptibility to any of five organophosphorus insecticides. In fact, larvae from Florida were more susceptible to malathion than the larvae from Georgia. Adults from Georgia were 7.8 times more susceptible to DDT and adults from Florida were 2.4 times more susceptible to malathion.

In October, 1961 the Indian River Mosquito Control District treated a large brood of *Ae. taeniorhynchus* in a pickleweed (*Batis-Salicornia*) marsh approximately 10 acres in size; the marsh had no tree canopy. Two gallons per acre of DDT emulsion containing 0.5 lb. DDT per gallon were applied by airplane. Inspection 24 hours after treatment showed no significant reduction in the larval population. Larvae from a nearby marsh had an LC-50 of .02 p.p.m. to DDT in 1961, theoretically a susceptible level (Fig. 1).

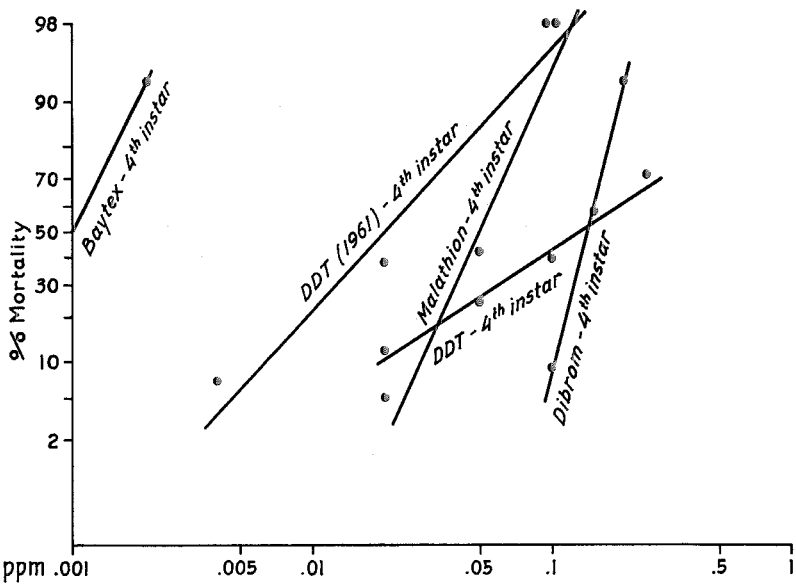

FIG. 1.—Dosage-mortality curves for several insecticides against larvae of *Aedes taeniorhynchus* (Wied.) in the WHO Resistance Test, 1961 and 1964. (Mortalities for Baytex at 0.008 and 0.004 p.p.m. were 23% and 6% respectively).

Aerial spray tests were conducted by the Entomological Research Center against caged adult mosquitoes on a grass landing strip during 1963 with *Ae. taeniorhynchus* and *Cu. nigripalpus* included in each test. In tests conducted on the same day, DDT at 0.4 lb. per acre in one gallon of diesel oil killed only 19 percent of the *Aedes* and 64 percent of the *Culex;* malathion at 0.2 lb. killed 99 percent of *Aedes* and 98 percent of *Culex;* and Dibrom at 0.1 lb. in water emulsion and in oil killed 100 percent of both species, as did malathion at 0.3 lb. in oil (unpublished data).

Aedes larvae collected from salt marshes in Indian River County in 1964, where no chlorinated hydrocarbons have been used since 1955, had an LC-50 for DDT in the WHO Resistance Test of 0.15 p.p.m. (Table 1; Fig. 1). Adults of *Aedes* reared from larvae collected in these marshes had an LC-50 greater than 4 percent for one hour exposure in the WHO adult test and 3.4 percent for 4 hours exposure. The LC-50 for *Cu. nigripalpus* to DDT in these tests was greater than 4 percent for both exposure periods (Table 2; Fig. 3). It is concluded that there has been no significant reversion, if any, to DDT susceptibility within this *Ae. taeniorhynchus* population during the past 9 years.

TABLE 1.—Susceptibility of larvae of *Culex nigripalpus* Theob. and *Aedes taeniorhynchus* (Wied.) to several insecticides in the WHO Resistance Test.[1]

Insecticide	Instar	LC 50—p.p.m. *Cu. nig.*	LC 50—p.p.m. *Ae. taen.*
DDT-1961	4	..	0.023
DDT	3	0.280	..
	4	..	0.150
Malathion	3	0.028	..
	4	0.034	0.050
Baytex	3	0.002	..
	4	0.003	0.001
Dibrom	4	0.047	0.140

[1] All tests conducted in 1964 except as indicated.

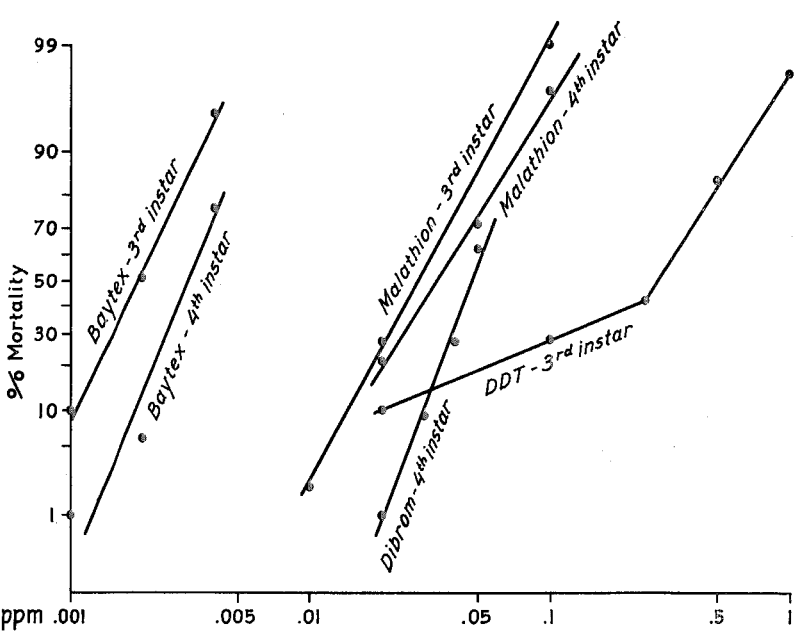

FIG. 2.—Dosage-mortality curves for several insecticides against larvae of *Culex nigripalpus* Theob. in the WHO Resistance Test, 1964.

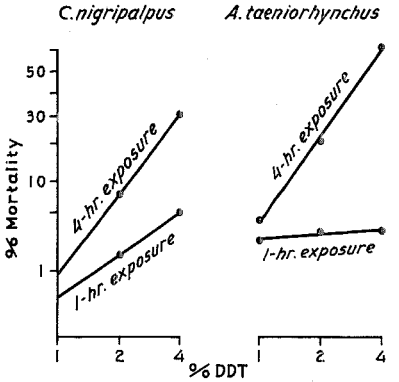

FIG. 3.—Dosage-mortality curves for DDT against adults of *Culex nigripalpus* Theob. and *Aedes taeniorhynchus* (Wied.) in the WHO Resistance Test, 1964.

The poor results with DDT against *Cu. nigripalpus* in these tests cannot be ascribed to physiological resistance resulting from selection pressure, because this species was never the object of planned control operations in Florida with chlorinated hydrocarbons. A more likely explanation is a greater natural resistance of this species to DDT. Also, there is no ready explanation for the low LC-50 of DDT to *Ae. taeniorhynchus* larvae from these same marshes in 1961 (Table 1).

Evans *et al.* (1960) reported that larvae of *Aedes aegypti* from Miami were 5.4 times more resistant to DDT at the LC-50 level than larvae from New Orleans and suggested that DDT resistance might be developing in *aegypti* at Miami. Porter *et al.* (1961) extended these tests and confirmed the resistance of *Ae. aegypti* in Miami to DDT. Abedi and Brown (1961) reported that *Aedes aegypti* originating from Key West, Florida were tolerant to DDT, the initial LC-50 being 0.3 p.p.m. These authors showed further that selection with DDT through the fourth generation increased the DDT-tolerance by 7 times.

TABLE 2.—Susceptibility of adults of *Culex nigripalpus* Theob. and *Aedes taeniorhynchus* (Wied.) to DDT in the WHO Resistance Test.

Insecticide	Exposure time-hrs.	LC 50—% toxicant	
		Cu. nig.	*Ae. taen.*
DDT	1	>4	>4
	4	>4	3.4

Data on the susceptibility of other problem mosquitoes in Florida to chlorinated hydrocarbons are at best incomplete. In comparative thermal aerosol tests conducted at Vero Beach in 1957, it was shown that *Culex quinquefasciatus* adults from Indian River County were slightly less susceptible to DDT than were DDT-resistant *Ae. taeniorhynchus;* poor kills also were obtained against *Psorophora confinnis;* whereas kills with DDT against *Aedes aegypti* and *Anopheles quadrimaculatus* from laboratory colonies, and against *Psorophora ciliata* from the field, were equal to or superior to those with malathion (Rogers and Rathburn, 1958).

ORGANOPHOSPHATES. Reports by Gjullin and Peters (1955) and Culver, Caplan and Batchelor (1955) in California and by Smith (1956) in Florida demonstrated the effectiveness and safety of malathion for area control of DDT-resistant adult mosquitoes. These reports stimulated research with organophosphates as mosquito adulticides at the Entomological Research Center at Vero Beach, Florida commencing in 1956.

Because of the experience with DDT resistance, the Florida State Board of Health in 1957 recommended to the Florida Mosquito Control Districts that the organophosphates be used only as space treatments for the control of adult mosquitoes, a program that is imperative for a subtropical tourist state like Florida. The purpose of this recommendation was to try to avoid or delay resistance to the organophosphates, which could be expected to occur quickly as a result of selection pressure if used on larval populations.

Tests with malathion in thermal aerosol at 8 oz. (actual) per gallon in No. 2 diesel oil, applied at 40 gallons per hour, at a vehicle speed of 5 miles per hour, gave an average kill of 93 percent of caged DDT-resistant *Aedes taeniorhynchus* in

1956. This test has been repeated periodically since that time with no reduction in kill or indication of resistance. The average percent kill in this test in 1963 was 98 percent (Table 3). Thus, malathion has been used as an adulticide in Florida for 8 consecutive years with no indication of resistance. This is attributed to the cooperation of the Florida Mosquito Control districts in complying with the recommendation of the Florida State Board of Health to avoid using these organic compounds as larvicides.

Keller and Chapman (1953) (Also see Brown, 1958, 1961; and Micks *et al.* 1961) Brevard County marshes that had received intensive treatment with DDT were reported that salt-marsh *Aedes* larvae from slightly more tolerant of EPN and malathion than larvae from nearby marshes that had been treated only occasionally with DDT. However, since no organophosphates had been used for mosquito control in these marshes prior to the time of these tests, this slight difference in larval susceptibility must be explained by vigor tolerance or some other phenomenon. The organophosphates have been used successfully for the control of adult mosquitoes in the vicinity of these marshes since 1956.

TABLE 3.—Thermal aerosol tests with malathion [1] against *Aedes taeniorhynchus* (Wied.), 1956–1963.

Year	No. of tests	Percent mortality
1956	8	93
1957	23	90
1958	6	90
1961	5	92
1963	8	98

[1] Eight oz./gal. (actual) in diesel oil applied at 40 gals./hr., vehicle speed of 5 miles per hour.

Of course, it cannot be stated that resistance will not develop eventually when these compounds are used only as space treatments against adults, but this approach to the resistance problem has worked well in Florida for the past 8 years, where up to 1¾ millions of gallons of formulated insecticides are used annually for control of adult mosquitoes.

Present dosage recommendations for ground aerosol operations with malathion are 6 oz. per gallon for control of *Aedes taeniorhynchus* and *Ae. sollicitans* and 8 oz. per gallon against *Culex nigripalpus*, an encephalitis vector. Dibrom (naled) is used at 1½ oz. against *Ae. taeniorhynchus* and 1¾ oz. against *Cu. nigripalpus*. Baytex (fenthion) is recommended at 1¼ oz. per gallon against *Ae. taeniorhynchus* in ground fogging. This insecticide has not been tested against other species as yet. These dosage recommendations are based upon a discharge rate of 40 gallons per hour, vehicle speed of 5 miles per hour, and a swath of 300 to 400 feet, or one city block.

Malathion, Dibrom, and Baytex presently are the only insecticides recommended for control of adult mosquitoes in Florida.

LARVICIDES. Although larviciding alone is not regarded as a practical procedure for mosquito control in Florida because of the unique conditions that characterize mosquito production in the State, the great value of larvidices is fully appreciated.

In keeping with the policy of avoiding the new organic insecticides for larviciding, only granular paris green and No. 2 diesel oil are currently recommended for larviciding in Florida. Research with granular formulations of paris green during the past several years has resulted in a larvicide that is effective against most of the important species in the State and is reasonable in cost when compared with other granular larvicides. For aerial application, it is necessary to use granular formulations for larviciding in many of the larval habitats in Florida.

Diesel oil is still widely used for ground larviciding, and research on improved formulations and methods of application is being pursued. Oil still has many advantages over other larvicides, provided the cost can be reduced.

DISCUSSION. Although the chlorinated

hydrocarbon insecticides have not been used extensively in Florida during the past 9 years, the salt-marsh *Aedes*, and possibly other species, are still highly resistant to DDT. In an effort to avoid or delay resistance to the organophosphates, these insecticides have only been used as space treatments for the control of adult mosquitoes, not for larviciding. This procedure has worked well for the past 8 years, there being no confirmed report of physiological resistance to the organophosphates in the State at this time.

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