*Literature Cited*

ABDEL-MALEK, ALBERT. 1948. Plant hormones (auxins) as a factor in hatching of *Aedes trivittatus* (Coquillett) eggs. *Ann. Ent. Soc. Amer.,* 49(1):51–56.

BODMAN, M. T., and NORMAN GANNON. 1950. Some habitats of eggs of *Aedes vexans. Jour. Econ. Ent.,* 43(4):547–548.

CONNELL, W. A. 1941. Hatching response of *Aedes sollicitans* eggs under selected and controlled environmental conditions. *Jour. Econ. Ent.,* 34(2):187–192.

FILSINGER, CARL. 1940. Distribution of *Aedes vexans* eggs. Proc. 28th Ann. Meet. New Jersey Mosq. Exterm. Assoc., 28:12–19.

GJULLIN, C. M. 1938. A machine for separating mosquito eggs from soil. USDA. BEPQ. Circular ET-135.

GJULLIN, C. M., HEGARTY, C. P., and BOLLEN, W. B. 1941. The necessity of a low oxygen concentration for the hatching of *Aedes* eggs. *Jour. Cell. and Comp. Physiol.,* 17(2):193–202.

HORSFALL, W. R. 1949. Hatching eggs of floodwater mosquitoes in media that promote plant growth. *Science* 110 (2863) 504–6.

# THE BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE'S CONTRIBUTION TO RESEARCH ON MOSQUITOES DURING 1951

HARRY H. STAGE

Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, United States Department of Agriculture

The research on mosquitoes carried on by the Bureau of Entomology and Plant Quarantine during 1951 is briefly summarized under the headings "Taxonomy" and "Biology and Control" as in my report for last year. Again this information has been made available to me by Alan Stone, taxonomist in Washington, by A. W. Lindquist, in charge of our Corvallis, Oregon, laboratory, and by W. C. McDuffie, in charge of our Orlando, Florida, laboratory. W. V. King, who was formerly in charge at Orlando, has been assigned new duties. They consist of analyzing data, revising and bringing up to date old publications, and preparing new manuscripts giving data on the results of research conducted at that station. As reported last year, the taxonomic investigations and those conducted at Corvallis are financed by regular appropriations from Congress, whereas those at Orlando are financed by funds allotted by the Department of Defense.

## TAXONOMY

Research at the United States National Museum. Alan Stone described a new species of *Aedes* from Tahiti early in 1952. Kathryn Sommerman was engaged to prepare pictorial keys to mosquitoes of medical importance in several overseas areas for use by the Army. Her work is financed by funds allotted the Bureau by the Department of the Army. A number of outside workers have been aided in their taxonomic studies, the most important being H. R. Foote in his study of the larvae of *Culex* (*Melanoconion*) species, E. F. Cooke in his study of the *Chaoborinae*, Marion Smith in her study of a new species of *Aedes* (*pseudodiantaeus*), G. W. Lassman in his description of a new *Psorophora,* and Elizabeth L. Marks in her study of *Aedes scutellaris* and its relatives. Several entomologists studied the mosquito collections at the United States National Museum before going to overseas assignments in the Orient and in Africa.

## BIOLOGY AND CONTROL

Research at the Corvallis, Oregon, Laboratory. *Mosquito resistance to insecticides.* —As far as can be determined, insecticides are satisfactorily controlling *Aedes* mos-

quitoes in the Pacific Northwest. As yet there are no indications that the floodwater species *A. vexans* and *A. sticticus* are developing resistance to DDT, but it is entirely possible they may do so in the future. Comparatively little control has been attempted against *A. dorsalis* in the irrigated sections of Washington and Oregon, hence it is much too soon to observe resistance by this species in that region.

In California, however, the situation is much different. *Aedes nigromaculis, A. dorsalis,* and *Culex tarsalis* are definitely resistant to DDT over a wide area in the San Joaquin Valley. Considerable specific information on this subject was obtained by a cooperative study with the California Department of Public Health's Bureau of Vector Control. C. M. Gjullin, of our Bureau, spent several months on this problem with the help of personnel assigned by the Bureau of Vector Control. Carefully designed experiments demonstrated that larvae of the species mentioned from treated fields had built up as much as 12 times more resistance to DDT than comparable larvae from untreated fields. Some resistance by *Aedes nigromaculis* to toxaphene, dieldrin, and aldrin was also observed. As the details of this research are to be reported by Gjullin and Peters, they will not be given here.

During the past two summers research has been directed towards controlling adult *Aedes* in the vicinity of summer homes around Forest Service installations and resort areas in the Cascade Mountains. Such areas have been protected from mosquito annoyance during daylight hours by applying about 2 pounds of DDT per acre over 1- to 5-acre tracts. A single treatment remained effective for several weeks. During a 2-hour period just before and after dusk, when the mosquitoes migrate from one place to another, the DDT residual treatment did not provide satisfactory control. Portable gasoline-powered sprayers were found to be satisfactory for applying this residual spray in bushy overgrowth. Pyrethrum and allethrin were found to be equally effective for the temporary control of mosquitoes during the dusk migration period. A. W. Lindquist has reported on the details of this research.

New chemicals for use as mosquito larvicides were tested in the laboratory, and efforts were made toward improving some of the old ones. None of the new chemicals were outstanding. Three new synergists for DDT improved the efficacy of the chlorinated hydrocarbon insecticides when tested against *Aedes* mosquito larvae resistant to DDT. However, they did not completely nullify the resistance.

A. R. Roth has operated a New Jersey light trap at Summer Lake, Oregon, during June and July 1950 and July and August 1951. His data on collections from an area where little information has been reported on mosquito ecology are rather interesting (Table 1).

TABLE 1.—Average number of mosquitoes caught nightly, Summer Lake, Oregon.

| Species [1] | 1950 | | 1951 | |
|---|---|---|---|---|
| | June | July | July | August |
| *Aedes dorsalis* | 147 | 283 | 69 | 53 |
| *Culex tarsalis* | 32 | 382 | 141 | 120 |
| *Culiseta inornata* | 29 | 73 | 281 | 203 |
| *Anopheles freeborni* | 7 | 44 | 10 | 13 |

[1] A few *Aedes campestris* and *A. flavescens* were also taken.

Research at the Orlando, Florida, Laboratory. Of the thousands of chemicals that have been tested as mosquito repellents, less than a score have proved highly effective and safe for unrestricted application to the skin. Our experience has shown that mixtures of several good repellents are effective against a wider range of species and on more individuals than any one repellent used alone.

Some of the more effective mixtures against several species of *Aedes* are (1) dimethyl phthalate 4 parts, 2-ethyl-1, 3-hexanediol 3 parts, and dimethyl carbate 3 parts; (2) dimethyl phthalate 4 parts, 2-ethyl-1, 3-hexanediol 3 parts, and *N,N*-diethylsuccinamate 3 parts.

Several of the most effective mixtures against *Aedes* mosquitoes proved relatively ineffective against *Anopheles quadrimaculatus.*

A number of laboratory and field tests were made with insecticidal materials and formulations in areas where salt-marsh mosquitoes were moderately or highly resistant to DDT. Emulsions of dieldrin were slightly more effective than emulsions of chlordane, and both were considerably more effective than pellets containing the same materials. Nearly perfect control of *Aedes sollicitans* and *A. taeniorhynchus,* both highly resistant to DDT, was obtained with ground sprayers applying from 0.05 to 0.2 pound of dieldrin per acre. Airplane sprays were ineffective where dieldrin was applied at the rate of 0.05 and 0.1 pound per acre, whereas at a dosage of 0.2 pound they gave nearly perfect kills. The poor results obtained with the lower dosages were no doubt due to poor penetration of the insecticide through the foliage.

Additional field tests were made against salt-marsh mosquito larvae resistant to DDT to determine the effectiveness of several chemicals that had shown promise as synergists of DDT. Emulsions containing 5 parts of DDT and 1 part of synergist were applied at the rate of 5 pints per acre. Monoethyl phosphate was the only chemical that increased the effectiveness of DDT, and this increase was too small to be of practical significance. Some of the synergists tested were isobutyl acetate, phenyl diphenylphosphonate, 1-(3,4-dichlorobenzoyl)-2 phenylhydrazine, and DMC.

An interesting experiment was made in which the susceptibility of *Aedes taeniorhynchus* larvae from heavily treated marshes of Brevard and Sarasota Counties was compared with that of larvae from the occasionally treated Titusville Beach marsh in Brevard County. Larvae from each of the two areas were treated with DDT, lindane, and dieldrin. The larvae from the heavily treated marshes showed a higher degree of resistance to DDT and were slightly more resistant to lindane and dieldrin than were the larvae from the lightly treated breeding areas.

A series of tests was made to determine the effectiveness and practicability of outdoor residual treatments of several insecticides against *Aedes taeniorhynchus* and *A. sollicitans* adults around isolated 2-acre home plots. Lindane and BHC containing 40 per cent of the gamma isomer, the most effective materials tested, gave good control for 17 days when applied at a dosage as low as 0.5 pound of the chemical per acre. Dieldrin was comparable in effectiveness for 13 days when applied at the rate of 2 pounds per acre. DDT and chlordane were the least effective of the insecticides tested, although at 1 and 2 pounds per acre both gave good controls for 3 to 7 days after treatment. These treatments greatly reduced daytime annoyance from mosquitoes, but during the evening when mosquitoes were active they were observed biting and the treatments appeared ineffective. It was apparent, however, that the mosquitoes were destroyed after resting several hours among the treated foliage in the vicinity of the home plot. When the pressure of the mosquito population outside the treated plot was sufficiently great, the mosquitoes would move into the treated area but did not die until after they had severely annoyed the occupants of the area.

Considerable data were obtained on the effectiveness of prehatching treatments in areas where the salt-marsh larvae were resistant to DDT. Dieldrin emulsions or wettable-powder suspensions applied at the rates of 0.5 and 1.0 pound of dieldrin per acre gave satisfactory control after three and four floodings. The suspensions also gave good control after two floodings when applied at the rate of 0.2 pound of dieldrin per acre. Emulsions at 0.1 and 0.2 pound of dieldrin and suspensions at 0.1 pound of dieldrin per acre were relatively ineffective.

Toxaphene emulsions and suspensions at 1.0 pound of toxaphene per acre gave excellent control after three floodings. The emulsions gave inconsistent results at lower dosages, but excellent control was obtained with the suspensions at 0.2 pound per acre after one flooding.