ico). University of California Press, Berkeley. 360 pp.
Husbands, R. C. 1969. An improved technique of collecting mosquito larvae for control operations. Calif. Vector Views 16:67–69, 72.
McLintock, J. and J. G. Rempel. 1963. Midsummer mosquito abundance in Southern Saskatchewan. 1963. Mosq. News 23(3):242–249.
McLintock, J., A. N. Burton, H. Dillenberg and J. G. Rempel. 1966. Ecological factors in the 1963 outbreaks of western encephalitis in Saskatchewan. Can. J. Public Health 57:561–575.
Mitchell, J., H. C. Moss and J. S. Clayton. 1944. Soil survey of Southern Saskatchewan. Soil Survey Rept. No. 12, Univ. of Saskatchewan, Sask.
Rempel, J. G. 1950. A guide to the mosquito larvae of Western Canada. Canadian J. of Res., D, 28:207–248.
Rempel, J. G. 1953. The mosquitoes of Saskatchewan. Canad. J. Zool. 31:433–509.
Shemanchuk, J. A., F. J. H. Fredeen and A. M. Kristjanson. 1955. Studies on flight range and dispersal habits of *Aedes flavescens* (Müller) (Diptera: Culcidae) tagged with radio-phosphorus. Canad. Ent. 87:376–379.
Stewart, W. W. A. 1970. A modified CDC light trap. Mosq. News 30(2):188–191.

MOSQUITO ACTIVITY IN TEXAS DURING THE 1971 OUTBREAK OF VENEZUELAN EQUINE ENCEPHALITIS (VEE). I. VECTOR POTENTIAL FOR VEE IN THE TEXAS RICE BELT REGION[1]

J. K. OLSON AND W. H. NEWTON[2]

Department of Entomology, Texas A&M University, College Station, Texas 77843

INTRODUCTION. The VEE Control Task Force, organized to suppress the outbreak of Venezuelan equine encephalitis (VEE) in Texas during 1971, involved personnel and expertise from a wide variety of governmental and scientific disciplines (Spears, 1972). The Department of Entomology at Texas A&M University contributed to the control effort by providing the VEE Vector Control Staff with current information on the relative size and species composition of adult mosquito populations in the regions of Texas most seriously affected by the epidemic. This information was obtained by means of an adult mosquito surveillance program initiated in May, 1971. Our surveillance program was designed to complement similar activities of other agencies concerned with the study and control of the 1971 VEE outbreak and eventually included 38 Texas counties.

One phase of the Texas A&M mosquito survey program was devoted to the assessment of adult mosquito activity in the Texas rice belt (Fig. 1) and extended from 22 July to 4 August 1971. Most of the land upon which rice is grown is in the northern half of a vegetational area of Texas designated by Gould (1969) as the "Gulf Prairies and Marshes Area." As Gould's designation implies, this area is quite level and drainage is relatively slow; thus, there are numerous habitats, in addition to those occurring in the ricelands proper, which have the potential for supporting large mosquito populations. At least 50 species of mosquitoes are known to occur in this region of the state (Hill *et al.*, 1958); and by the time that we began our survey of the rice belt, ten of these species had already been incriminated as being involved in the 1971 VEE outbreak in northern Mexico and in the lower Rio Grande Valley of Texas

[1] This research was conducted in cooperation with the Agricultural Research Service, U. S. Department of Agriculture and approved for publication as TA 10532 by the Director, Texas Agricultural Experiment Station.

[2] Assistant Professor and Extension Entomologist, respectively.

TABLE 1.—Number of female mosquitoes collected per trap for light traps set in the Texas Rice Belt, 22 July to 4 August 1971.

Species	No. of mosquitoes collected per trap in Ricelands (36 Traps)	Gulf prairie lowlands (57 Traps)	Coastal marshlands (3 Traps)	All habitats combined (96 Traps)
Aedes sollicitans[a]	7.0	1.5	149.3	8.2
Aedes taeniorhynchus[a]	11.3	27.1	34.3	21.4
Aedes triseriatus	0.1	....	....	<0.1
Aedes vexans	<0.1	0.4	....	0.3
Anopheles crucians[a]	111.8	8.7	318.0	57.0
Anopheles pseudopuntipennis[a]	....	<0.1	....	<0.1
Anopheles quadrimaculatus	81.8	23.0	13.3	44.7
Culex nigripalpus[b]	0.2	2.2	....	1.4
Culex quinquefasciatus	....	0.2	....	0.2
Culex salinarius	165.0	6.6	81.0	68.3
Culex (Melanoconion) spp.[a]	3.2	7.4	....	5.6
Culex species	6.5	0.8	....	3.0
Mansonia perturbans	<0.1	<0.1	....	0.1
Psorophora ciliata[a]	1.3	0.1	....	0.1
Psorophora confinnis[a]	97.3	27.3	177.0	58.2
Psorophora cyanescens[a]	<0.1	<0.1	....	<0.1
Psorophora discolor[a]	<0.1	<0.1	....	<0.1
Psorophora ferox	....	<0.1	....	<0.1
Uranotaenia lowii	....	<0.1	....	<0.1
All species	485.6	105.5	773.0	268.9

[a] Species incriminated as possible vectors of VEE in south Texas in 1971 (Sudia and Newhouse, 1971).
[b] Species incriminated as a possible vector in Guatemala in 1969 (Sudia *et al.*, 1971).

(Sudia and Newhouse, 1971). Eight of the incriminated species are noted in Table 1 of this report. *Culex salinarius* Coquillett was included in the original list of possible vectors for VEE in Texas; however, it was excluded later on the basis of further tests.[3]

Our assessment of mosquito activity in the rice-producing region of Texas was initiated at the request of those charged with the responsibility of coordinating Phase II of the VEE Vector Control Program. Vector control efforts under Phase II were designed to suppress adult mosquito populations in an area extending from the lower Rio Grande River Valley, northward along the Texas Gulf Coast and eastward into Louisiana (Spears, 1972). Our information regarding the level of mosquito activity in the Texas rice belt was relayed daily to the VEE Task Force Center located in Houston, Texas. This information, along with that provided by other agencies conducting surveys elsewhere in the state, was used by the VEE Vector Control Staff in determining the specific acreages to be treated with aerial applications of insecticide.

The results presented herein reflect the status of female mosquito populations within the Texas rice belt for the period of 22 July to 4 August 1971. As of 22 July, VEE had been in the state for at least 3 weeks and was spreading northward along the Texas coastline; the vac-

[3] W. D. Sudia, personal communications.

cination of horses was not complete; and the mosquito control program involving the combined efforts of the U. S. Air Force (Pinkovsky, 1972), commercial applicators and local mosquito control districts was in progress.

METHODS. The field and laboratory methods used during the collection and processing of adult mosquitoes were similar to those described by Sudia and Chamberlain (1967). CDC miniature light traps (Sudia and Chamberlain, 1962), supplemented with bags of dry ice to increase their attractance for mosquitoes (Newhouse *et al.*, 1966), were the primary means for sampling female mosquito populations. In some instances, resting sites, such as horse barns and culverts, were also examined for mosquito activity. Mosquito samples from light traps operated from sunset to sunrise each trap night were sealed in vials and stored in a frozen state. In the field, the samples were held on dry ice; and in the laboratory, they were stored in an ultra-low temperature cabinet (—50° C). Mosquito collections were identified in the laboratory on chill tables (Sudia *et al.*, 1965) by trained technicians using a combination of several taxonomic keys (Carpenter and LaCasse, 1955; Stojanovich, 1964; Texas State Department of Health, 1944). Identifications were periodically checked by the senior author to insure their accuracy. Portions of each week's mosquito samples were pooled by species, date and location and subsequently stored in an ultra-low temperature cabinet for additional laboratory analysis for the presence of arboviruses.

The rice belt counties and areas included in the 1971 adult mosquito surveillance program are shown in Figure 1. The specific counties surveyed and trap locations within a given county varied from night to night for the period of 22 July to 4 August. These variations were necessary in order to satisfy the needs of those in charge of coordinating the mosquito control program. Each night, light traps were placed in at least 8 different locations in the 11-county area. During the survey period, mosquito populations were sampled at a total of 96 separate sites (one trap per site): 36 sites were in ricelands proper; 57 were in other gulf prairie lowland situations away from the coastline and 3 were in the coastal marshlands. All of these sites were in locations which had not been treated with insecticide prior to our surveys. Twelve additional sites were sampled for adult mosquito activity approximately two days after these particular sites had been treated with malathion at a rate of 2.6-3.0 ounces per acre (ULV). Seven of these latter sites were in ricelands and five were in other poorly drained, low areas inland from the coast.

RESULTS. As shown in Table 1, 18 species of mosquitoes (not including unidentified *Culex* species), representing 6 genera, were present in the combined light trap collections from the three major habitat types surveyed in the Texas rice-producing region during 22 July to 4 August 1971. Collections from the gulf prairie lowlands included representatives of 17 species while those from the ricelands and coastal marshlands contained representatives of 14 and 6 species respectively. *Aedes sollicitans* (Walker), *A. taeniorhynchus* (Wiedemann), *Anopheles crucians* Wiedemann, *A. quadrimaculatus* Say, *Culex salinarius* Coquillett and *Psorophora confinnis* (Lynch Arribálzaga) were common to collections from each of the major habitats; and together they constituted 95.9 percent of the total collections from all habitats sampled.

The trapping averages summarized in Table 1 indicate that the coastal marshlands supported the highest numbers of adult mosquitoes at the time of our surveys. The collection average for all traps set in the marshlands exceeded those for traps set in ricelands and gulf prairie lowlands by factors of 1.6 and 7.3, respectively. *Anopheles crucians, Aedes sollicitans* and *Psorophora confinnis* were predominant species in the marshlands, and together they comprised 83.3 percent of

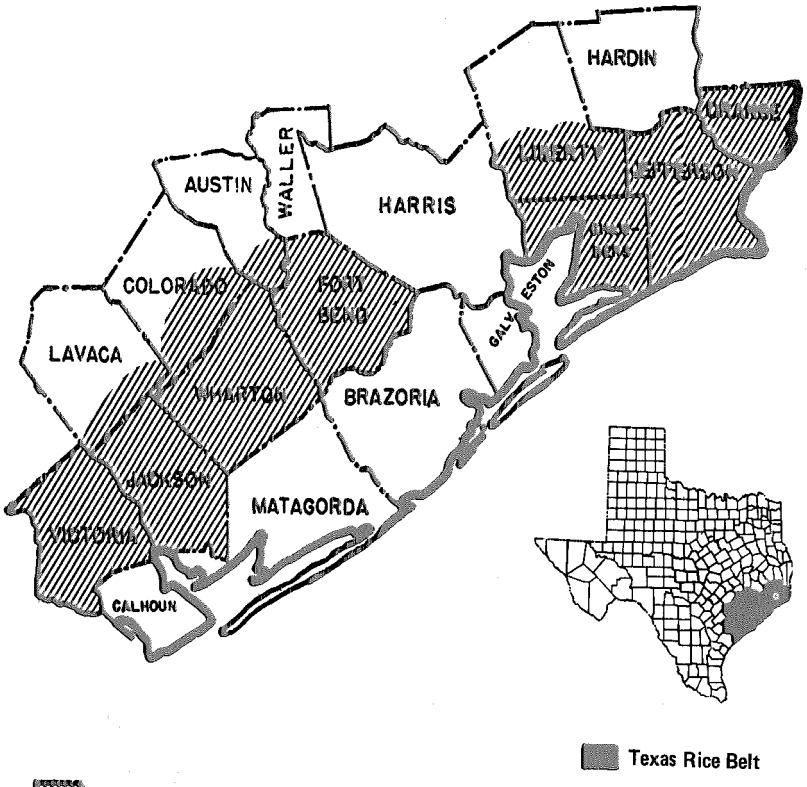

Fig. 1.—Areas of the Texas Rice Belt surveyed for female mosquito activity by Texas A&M University during 22 July–4 August 1971.

TABLE 2.—Mosquito collection averages and frequency of collection for CDC miniature light traps set in areas not treated with malathion and for those set in areas aerially treated with malathion (2.6–3.0 oz./acre, ULV) 28–29 July, 1971.

Habitat type	No. of mosquitoes per trap			Frequency of collection**	
	Untreated	Treated	Untreated: treated ratio*	Untreated	Treated
Ricelands	52.9 (8 traps)	0.0 (7 traps)	....	0.88	0.00
Gulf prairie lowlands	170.3 (6 traps)	3.2 (5 traps)	53.2	1.00	0.80

* Untreated:Treated Ratio = $\frac{\text{Trap average for untreated area}}{\text{Trap average for treated area}}$.

** Frequency of Collection = $\frac{\text{No. of traps collecting mosquitoes}}{\text{Total no. of traps set in a given habitat}}$.

the total number of mosquitoes collected in coastal marshland traps.

As for the adult mosquito populations in the gulf prairie habitats away from the coastal marches, the relative abundance in ricelands was generally greater than in other gulf lowland situations. The collection average for all traps set in the the ricelands was 4.6 times greater than that for the traps set in the lowlands. *Anopheles crucians, A. quadrimaculatus, Culex salinarius* and *Psorophora confinnis* were the predominant species in the ricelands and constituted 93.8 percent of the total collections from riceland sites. *Anopheles quadrimaculatus* and *Psorophora confinnis* were also predominant in collections from the other gulf prairie lowland situations and together with *Aedes taeniorhynchus* comprised 73.4 percent of the total trap collections from this latter habitat. It should be noted here that *A. quadrimaculatus* was the species most commonly found resting in horse barns examined during the course of our surveys.

The results presented thus far reflect the status of the adult mosquito activity within areas of the Texas rice-growing region which had not been treated with insecticide prior to our surveys. During the last week of July we had occasion to assess the effectiveness of aerial applications of malathion (2.6–3.0 oz. per acre ULV) on existing adult mosquito populations in Wharton and Victoria Counties (Fig. 1). In each county, traps were set in both treated areas and nearby untreated areas within a day after the initial application of insecticide was accomplished. The maximum distance between nontreated and treated sites was 25 miles. Trapping results for these sites are summarized in Table 2. The malathion treatments appeared to have their greatest impact upon riceland mosquito populations. In the other lowland situations, the mosquito populations were significantly reduced; however, there was some adult mosquito activity after treatment as is evidenced by the frequency of traps collecting mosquitoes within the treated lowland habitats. Specimens of *Aedes taeniorhynchus, Anopheles crucians, A. quadrimaculatus, Culex salinarius* and *Psorophora confinnis* were present in the trap collections from the treated lowlands. These same species comprised 86.2 percent of the total collections from traps set in nontreated lowlands elsewhere in the two counties.

DISCUSSION. The primary objective of our 1971 mosquito surveillance centered in the Texas rice belt was to assess the size of and potential for local mosquito populations to support the spread of VEE in this region of the state. Since the IB epidemic strain of VEE virus was the one responsible for the 1971 outbreak in Texas (Sudia *et al.*, 1972), we concerned ourselves, for the most part, with assessing the status of mosquito species which were either proven or incriminated as possible vectors of this particular strain of virus as of that time. Light trap collections from the rice-growing region of the northern Texas Coastal Zone for the period of 22 July to 4 August included representatives of at least 8 of the 11 species incriminated by the Arbovirus Ecology Laboratory, Arbovirology Unit, Center for Disease Control, as being involved in the 1971 VEE outbreak in northern Mexico and Texas (Sudia and Newhouse, 1971). The eight species were *Aedes sollicitans, A. taeniorhynchus, Anopheles crucians, A. pseudopunctipennis* Theobald, *Psorophora ciliata* (Fabricius), *P. confinnis, P. cyanescens* (Coquillett) and *P. discolor* (Coquillett) (Table 1). Representatives of *Culex* species belonging to the subgenus, *Melanoconion,* were also present in our collections. Whether or not these latter species were the same as those collected in south Texas is not certain. Although *Culex nigripalpus* Theobald was not incriminated as a vector in Texas, it was implicated as a possible vector during the 1969 outbreak of VEE in Guatemala (Sudia *et al.*, 1971). Since this species was collected in small numbers by our traps set in the ricelands and other gulf prairie lowland

situations, it, too, should be added to the list of potential VEE vectors which were present in the rice-producing region of Texas during 1971.

Of the more than eight suspected VEE vector species present as adults in the Texas rice belt during July and August 1971, *Aedes sollicitans, Ae. taeniorhynchus, Anopheles crucians* and *Psorophora confinnis* were the ones most commonly occurring in light trap collections from each of the major habitats surveyed, and together, they comprised 53.9 percent of the combined collections from all habitats. The prevalence of *Aedes sollicitans* and *Psorophora confinnis* was of special concern since these two species were included in the list of south Texas mosquitoes from which the greatest number of VEE-like isolates were obtained during 1971 (Sudia and Newhouse, 1971). In addition, *P. confinnis* has been implicated as a primary vector of the IB strain of VEE not only on the basis of minimum field infection rates (Sudia *et al.*, 1971) but also on the basis of experimental infection and transmission rates (Sudia *et al.*, 1971).

Adult mosquito populations in each of the major habitats were relatively low (Table 1) and reflected the severity of the drought which prevailed over much of the Texas Coastal Zone throughout the spring and summer of 1971. However, in spite of the low numbers of mosquitoes, the potential for the spread of VEE into the counties that we surveyed was considered to be quite high as of July. This conclusion was based on the following facts: (1) VEE was known to be present in horses living in nearby counties (Sudia *et al.*, 1972); (2) adult mosquito populations within the Texas rice-growing region were often found in close proximity to horses and included several species considered as proven or possible vectors of IB-VEE and (3) the vaccination of the more than 35,000 horses residing in the 11-county area included in our survey program was not complete. This third item was an important factor since horses are not only susceptible to IB-VEE but also, once infected, they can develop high enough virus levels in their blood to infect a relatively high percentage of vectors which feed upon them (Henderson *et al.*, 1971; Sudia *et al.*, 1971). Thus, the presence of susceptible horses proximal to vector populations in the Texas rice belt provided a host-vector association which may well have supported the local spread of VEE even though the vector populations were low. Since no known cases of VEE occurred in any of the 11 counties included in our survey program, it may be concluded that the combined control efforts involving aerial applications of insecticides for mosquito control and completion of the equine vaccination program were effective in suppressing the disease in this region of Texas.

References Cited

Carpenter, S. J. and W. J. LaCasse. 1955. Mosquitoes of North America. Berkeley and Los Angeles: University of California Press. vi + 360 pp.

Gould, F. W. 1969. Texas plants, a check list and ecological summary. Texas Agric. Exp. Sta. MP-585/Revised. 121 pp.

Henderson, B. E., W. A. Chappell, J. G. Johnston, Jr. and W. D. Sudia. 1971. Experimental infection of horses with three strains of Venezuelan equine encephalomyelitis virus. I. Clinical and virological studies. Am. J. Epid. 93: 194–205.

Hill, S. O., B. J. Smittle and F. M. Philips. 1958. Distribution of mosquitoes in the Fourth U. S. Army Area. Entomology Div., 4th U. S. Army Medical Laboratory, Fort Sam Houston, Texas. 155 pp.

Newhouse, V. F., R. W. Chamberlain, J. G. Johnston and W. D. Sudia. 1966. Use of dry ice to increase mosquito catches of the CDC Miniature Light Trap. Mosq. News 26:30–35.

Pinkovsky, D. D. 1972. United States Air Force spray activities in operation combat VEE. Mosq. News 32:332–334.

Spears, J. F. 1972. VEE control—the largest spray operation ever. *In* Chem and Commercial Fertilizer, December 1971–January 1972.

Stojanovich, C. J. 1964. Pictorial key to adult female mosquitoes of Texas, Parts I–IV. U. S. Dept. Hlth. Educ. Wel., Pub. Hlth. Ser., Communicable Dis. Cent. 4 pp.

Sudia, W. D., C. H. Calisher, V. F. Newhouse, L. D. Beadle, J. G. Johnston, Jr., Gladys Sather, R. W. Chamberlain, R. O. Hayes, B. D. Francy,

D. A. Eliason, and J. V. Smith. 1972. *In* Vector Control Briefs, February:5–9.
Sudia, W. D. and R. W. Chamberlain. 1962. Battery-operated light trap, an improved model. Mosq. News 22:126–129.
Sudia, W. D. and R. W. Chamberlain. 1967. Collection and processing of medically important arthropods for arbovirus isolation. U. S. Dept. Hlth. Educ. Wel., Pub. Hlth. Ser., Nat. Communicable Dis. Cent. 29 pp.
Sudia, W. D., R. W. Chamberlain and M. I. Collier. 1965. CDC entomological chill table, a refrigerated unit for use in processing mosquitoes for arbovirus isolation study. Mosq. News 25:385–389.
Sudia, W. D., R. D. Lord, V. F. Newhouse, D. L. Miller, and R. E. Kissling. 1971. Vector-host studies of an epizootic of Venezuelan equine encephalomyelitis in Guatemala, 1969. Am. J. Epid. 93:137–143.
Sudia, W. D. and V. F. Newhouse. 1971. Venezuelan equine encephalitis in Texas, 1971: Informational report. Mosq. News 31:350–351.
Sudia, W. D., V. F. Newhouse and B. E. Henderson. 1971. Experimental infection of horses with three strains of Venezuelan equine encephalomyelitis virus. II. Experimental Vector studies. Am. J. Epid. 93:206–211.
Texas State Department of Health. 1944. The mosquitoes of Texas. Compiled by the Division of Medical Entomology, Bureau of Laboratories. Texas State Dept. Hlth. Publication No. E33-1244-2M-L180. 100 pp.

EFFECTIVENESS OF SELECTED COMPOUNDS AS RESIDUES AGAINST ANOPHELINE ADULTS[1]

H. G. WILSON, G. C. LABRECQUE AND D. E. WEIDHAAS
Insects Affecting Man Research Laboratory, Agr. Res., Serv., USDA, Gainesville, Florida 32604

ABSTRACT. A group of 108 selected insecticides was tested at a rate of 1 g/m² as residual sprays against adult *Anopheles quadrimaculatus* Say. Twenty-four caused 100 percent mortality throughout the entire 6-month testing period.

INTRODUCTION. For a number of years one of the most effective methods of controlling anopheline mosquitoes has been the application of insecticidal residues to the walls and ceilings of buildings. However, the extensive use of some particularly effective insecticides throughout the world in vector control programs has caused resistance to appear. Therefore, since 1943, the Insects Affecting Man Research Laboratory located at Gainesville, Florida, has maintained a continuing program to evaluate selected compounds as alternative, effective, and economical residual insecticides against mosquitoes. Periodically we publish results of these studies. The present paper reports the results obtained with 108 compounds obtained from commercial sources.

MATERIALS AND METHODS. Acetone solutions of the compounds were sprayed on plywood panels at the rate of 1 g/m², then 1 week after treatment, 4 weeks after treatment, and every 4 weeks thereafter for 24 weeks (or until they became ineffective). Forty 1- to 2-day-old female mosquitoes (*Anopheles quadrimaculatus* Say) were exposed under half sections of petri dishes on the treated panels for 60 minutes. Then the mosquitoes were transferred to cylindrical screen cages, furnished cotton that had been saturated with 10 percent sugar solution, and held for 24-hour mortality counts. Panels were considered ineffective when they failed to produce at least 70 percent mortality at 2 consecutive tests. Enough panels were sprayed with each insecticide to avoid the

[1] This paper reflects the results of research only. Mention of a pesticide in this paper does not constitute a recommendation of this product by the USDA.