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January 31 – February 1-2, 1972

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W. Donald Murray, Secretary-Treasurer
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MOSQUITO ABATEMENT DISTRICTS

Senator Alan Short
San Joaquin County
31 East Channel Street, Stockton, California 95202

California's mosquito abatement districts are more or less at the focus of some of today's most hotly debated political issues. You spend some ten million dollars a year in property taxes, which is the tax that everyone, from local homeowners to the President of the United States, says must be lowered. You must deal with pesticides and all the related environmental issues in this new age of ecology. And your efforts are affected by the current state administrations highly publicized "cut, squeeze and trim" budgetary policies.

Probably the most volatile of these issues right now is that of property taxation. Because of the rising costs of education the tax has risen precipitously. Property taxes are increased virtually every year, mostly by the counties and school districts. People are aware of it, and unhappy with it and with the politicians who, year after year, have failed to deliver on their promises of property tax relief. Now the courts have taken an interest, and the President promises property tax relief financed by the federal government.

The level of property taxes bears no relationship to the amount and the quality of the government services they pay for. Some property taxpayers receive a low level of government services while others receive a high level of government services at the same tax rate. And it is far from easy to assign responsibility under this system of taxation. Nearly 6,000 overlapping units of local government impose property taxes in California. Even the most knowledgeable citizen has a difficult time tracing where his property tax dollar goes and what it buys.

The property tax is a much abused, much resented source of income, but it is not an invalid one. For all its faults, it has its merits. Indeed, it is essential to maintaining the balance of governments which makes our system work.

Only the property tax gives local government the flexibility to raise or to lower taxes annually in small amounts. and that power is the core of local government. Eliminate that power and local government becomes nothing more than an administrative unit for the state and national governments.

Furthermore, the property tax is justifiable because it can be, and should be related closely to services that benefit property. Schools have always had, at best, a tenuous relationship to property benefit. There is no direct connection between educational needs of children and the value of the neighborhoods they live in. On the other hand, a service such as that you provide, insuring a healthy environment and preventing a pest nuisance, surely enhances local property values and is therefore properly financed through property taxation.

Property taxpayers are not really aware of the value of your services until you stop providing them. But those taxpayers are aware of you as a part of their property tax bill. There is a very real danger that in this confused welter of resentment of property taxes, your function and the other legitimate functions of local government will be seriously impaired.

Unpopular as it may be, we must insist on the value of the property tax for certain government services, and show that not all the problems associated with the property tax are caused by the property tax.

It seems to me you face a similar dilemma in the environment field. On the one hand, the public needs and wants mosquitoes and other pests eliminated, but on the other hand there is growing public fear and opposition to the method of elimination –– the use of pesticides.

This is a dilemma that may outrun the ability to resolve it. While the public's opposition to pesticides is growing, so is the mosquito's biological resistance to chemical pesticides. The State Department of Public Health estimates that mosquitoes in ten percent of the irrigated pastures in abatement districts are already uncontrollable, and that percentage is growing rapidly.

I know that increasingly you are returning to older forms of biological control, but those methods cannot possibly keep up with the need for control. This fact, coupled with the rising human susceptibility to encephalitis resulting from the many years of successful mosquito control makes the need for applying new technology in this field literally a life and death matter.

This, it seems to me, is a proper role for state government. Normally, the state would be pursuing research in this field, but these are not normal times. The studies which were in progress at the University of California have been discontinued because of the Governor's cuts in the University's research budget. A newly begun study of mosquito habitat by the State Department of Public Health is also threatened with budget elimination.

Politically speaking, California's mosquito abatement districts face a precarious future. You face a state administration which is willing to perpetuate its economy image at the expense of important scientific research. And you face an electorate that is increasingly resentful of your source of income — the property tax.

It would seem that you have a very difficult selling job ahead, but it is worthwhile. I can assure you of the support and appreciation of many of us in the Legislature.

PANEL: CALIFORNIA'S INTEREST IN THE 1971 VENEZUELAN ENCEPHALITIS OUTBREAK IN MEXICO AND TEXAS

MODERATOR: William C. Reeves

University of California

School of Public Health, Berkeley, California 94720

I have been asked to provide an introductory overview of "California's Interest in the 1971 Venezuelan Equine Encephalitis Outbreak in Mexico and Texas" and to moderate the following presentations by an outstanding panel who will review the events of this past summer.

California has long been concerned with the protection of its horse and human populations from these mosquito-borne viruses that can cause inflammation of the brain-encephalitis. The interest originated historically in the early part of this century when epizootics raged in the horse populations of this and other western states. In the 1920's and early 1930's the disease was severe enough to threaten our agricultural economy that depended on horse power. The pioneering studies by Dr. K. F. Meyer and his co-workers from the University of California established that viruses caused encephalitis and it was soon learned that at least three viruses, Western equine encephalomyelitis (WEE), St. Louis encephalitis (SLE) and Eastern equine encephalomyelitis (EEE) occurred in North America and were transmitted by mosquitoes. In subsequent years additional viruses were isolated from mosquitoes, gnats and ticks and their wildlife hosts so that Dr. James Hardy could report to your annual Conference in 1970 on our knowledge of 15 such viruses that occur in California. He informed you that WEE, SLE, California encephalitis, Powassan, Rio Bravo Bat, Modoc, and Colorado Tick Fever viruses all had been associated with illnesses and that WEE, SLE, Turlock, Main Drain and Bluetongue viruses were associated with serious illnesses of domestic mammals.

In the ensuing years since mosquitoes were unveiled as important carriers of viruses in California there has developed in the state one of the world's outstanding programs of research and vector control. Much of the approximate $11,000,000 annual budget for organized mosquito control in the state is directed specifically at *Culex tarsalis* as the principal endemic and epidemic vector. If you review the record of proven cases of encephalitis in persons who resided in the state you find there were 640 laboratory confirmed WEE cases and 435 confirmed SLE cases during the 1950-1970 period. However, when you examine the record further there is a constant decrease in the annual incidence of cases in the period since 1960 until in the past several years there are only one or two cases. The above record is in marked contrast to an annual incidence of over 100 cases in the 1940's and a peak of 420 cases in 1952. My personal belief is that the preceding trend represents a proud record for mosquito control in this state.

While the preceding search for scientific knowledge and establishment of a control program was being accomplished, the public health and research establishments of California were maintaining an international watch with reference to two mosquito-borne viruses, Venezuelan equine encephalomyelitis (VEE) and Japanese B encephalitis. It is believed that these have an epidemic potential in the human and horse populations of our state if they are introduced. VEE virus, especially, has been intermittently surging and receding over an extensive area of South and Central America since its discovery in Venezuela in 1938. By 1963 we knew VEE virus was endemic in the rodents and mosquitoes of southern Mexico and Florida. By the spring of 1971 we knew the epizootic and epidemic variant of VEE virus was active over much of Central America and had extended northward along the Gulf Coast of Mexico. Several experts loudly predicted that VEE virus would invade Texas and other southern tier states in 1971 unless drastic and immediate action was taken before summer. Texas seemed to be the most likely port of entry but California shared in the concern. California's concerns can be summarized as follows:

1. We had just won a major battle to control WEE and SLE and certainly had no need for introduction of a new virus.
2. Our horse and human populations were highly susceptible to VEE virus as there was an epidemic potential.
3. A number of our most abundant mosquito species would be competent vectors of VEE virus and these included -*Culex tarsalis*, *Aedes nigromaculis*, *Aedes vexans*, *Psorophora confinnis* and *Anopheles freeborni.*
4. If the virus was introduced epidemic losses would be high, control would be costly and there could be no assurance that the virus would not become established permanently in the state.
5. We had to intensify our disease detection system to rapidly identify virus entry and broaden our diagnostic abil-

ity to include this exotic virus.

As most of you know VEE virus did gain entry into Texas in June 1971, broad news coverage and a defensive program were developed in California and the purpose of today's program is to review:

1. The events in Texas when the disease broke out in horses and people.
2. The control efforts in Texas and other parts of the United States.
3. The economic and political impacts of the program.
4. The current status and future potential for VEE activity in Texas and Mexico.
5. The specific actions taken in California in 1971 and our projected concerns for 1972.

PANEL: THE CENTER FOR DISEASE CONTROL ACTIVITIES

Archie D. Hess
Ecological Investigations Program
Post Office Box 551, Fort Collins, Colorado 80521

Center for Disease Control (CDC) investigators from the Epidemiology Program and the Laboratory Division in Atlanta and the Ecological Investigations Program, Fort Collins Laboratories, in Colorado, have collaborated in field and laboratory studies of the VEE invasion of the lower Rio Grande Valley of Texas. By the end of the season, there had been 86 isolations of the epidemic strain of VEE from equines and 88 laboratory confirmed human cases. The most recent isolation from equines was from a specimen collected on November 7, 1971, and the last onset of a human case was on October 2, 1971.

Virus isolations in the Atlanta laboratories revealed a wide range of mosquitoes infected with VEE virus. These included eleven species from five genera, mostly *Aedes* and *Psorophora*. This suggests that epizootic transmission may be carried out by a variety of species which feed upon the epizootic reservoir host (equines) as well as other large animals. If VEE reaches southern California, species such as *Aedes dorsalis* and *Aedes melanimon* might well become involved as epizootic and epidemic vectors.

An important question yet to be resolved is whether VEE has or will become established in an enzootic or endemic cycle in permanent foci. For the known endemic strains, this involves entirley different vector species (*Culex* mosquitoes of the subgenus *Melanoconion*) and reservoir hosts (rodents instead of equines). Preliminary studies by the Fort Collins staff in the epidemic area indicate a high VEE infection rate in jack rabbits and desert cottontails. This suggests that vectors other than mosquitoes (such as *Culicoides*) might become involved in the establishment of enzootic transmission cycles. The Fort Collins staff has determined that *Culex tarsalis* is involved in winter transmission of western encephalitis (another Group A virus) in the lower Rio Grande Valley. This species could probably serve as both an enzootic and epidemic vector of VEE because of its susceptibility to infection and the wide range of hosts upon which it feeds, including horses.

California and other states bordering the VEE outbreak area are justifiably concerned as to whether VEE has become entrenched in enzootic foci and whether there may be renewed enzootic and epidemic activity this coming season. CDC is collaborating with State health departments and other agencies in an intensive surveillance for VEE activity in the outbreak area and the establishment of monitoring stations to detect any extension of activity into peripheral areas of Louisiana, Oklahoma, Colorado, New Mexico, Arizona and California.

Details of CDC investigations on VEE will appear in forthcoming publications by the various investigators who have participated in the studies of the outbreak.

PANEL: THE UNITED STATES DEPARTMENT OF AGRICULTURE'S ACTIVITIES AGAINST VENEZUELAN EQUINE ENCEPHALITIS

Norvan Meyer
U. S. Department of Agriculture
Animal and Plant Health Inspection Service, Hyattsville, Maryland

Venezuelan equine encephalitis was the number one agricultural story in the United States for a number of weeks during the summer of 1971. Radio, TV and press coverage was greater than for any single activity of the Department of Agriculture in recent years.

The virus did spread into Texas, where it killed several hundred horses, although no one will ever know just how many. An official figure of 1,500 equine deaths in Texas has been given, but this is an estimate. There were at least 100 persons hospitalized, but there may have been many more.

The outbreak was serious enough that the Secretary of Agriculture declared it an emergency on July 9, 1971.

The fight against VEE was a big task, involving more than 4,000 persons at the height of the outbreak, including practicing veterinarians, State and Federal people, Department of Defense staff, Health, Education and Welfare staff, miscellaneous people from Gulf Coast states and California, and commercial concerns who provided necessary supplies.

The eradication program consisted of three different parts:

1. the control of vector mosquitoes
2. the quarantine of susceptible horses, and
3. the vaccination of susceptible animals.

Federal quarantines were applied to Texas on July 13, later to Louisiana, Arkansas, Oklahoma, New Mexico and Mississippi. Horses moving from these states required a certificate of health inspection and a vaccination at least 14 days prior to movement.

The U. S. Department of Agriculture furnished VEE vaccine for horses in the states of Texas, New Mexico, Arizona, California, Louisiana, Oklahoma, Arkansas, Mississippi, Alabama, Georgia, Florida, South Carolina, North Carolina, Virginia, Maryland, Delaware, New Jersey, Tennessee and Kentucky. The Department also paid private practicing veterinarians in these states for the cost of administering the vaccine. In a period of about three months, nearly 3,000,000 horses were vaccinated. Since August 25, 1971, a commercially licensed vaccine has been available and private practitioners have applied it in many additional states.

Since mosquitoes can carry the virus, an aerial spray program was deemed appropriate and necessary. This proved to be one of the largest aerial spray programs for control of insect vectors ever carried out. It was designed to reduce the vector populations in the most critical areas, and to do so as quickly as possible. These areas included the Gulf Coast from Brownsville north and along the Rio Grande River west. Very shortly after the program was started, the virus was found farther north than had been anticipated, so the control area was extended from the Falcon Dam on the Rio Grande River down to the Gulf, then up the Gulf Coast over to Lake Charles, Louisiana, a distance of about 545 miles. Arrangements to spray on the Mexico side of the Rio Grande River were contemplated but could not be cleared.

Responsibility for organizing this vector control program was assigned to the Plant Protection Division of the Agriculture Research Service. Spray planes of many types were used: nine PV2's, nine DC3's, three B17's, two C46's, one Constellation, and one Lodestar. The Department of Defense furnished eleven C123's and eight C47's. A ground to air communications facility was established. There were "chase" planes to determine that the proper areas were covered. On two successive days more than one million acres were sprayed. About 12.7 million acres were sprayed in this program, for the most part representing single coverage. Some of this coverage was by local mosquito control agencies in Texas. A major portion of the spray used was malathion, with dibrom also used in certain areas. Malathion was used at three oz per acre, dibrom at .75 oz per acre. Total cost of the spray operation was about 25 cents per acre. The entire spray program was completed in 35 days.

The Environmental Protection Agency worked closely with this program, and approvals were supplied in time to assure a successful program.

There have been criticisms that the Department of Agriculture was slow in getting the control program under way. However, the Department was aware of the outbreak in Mexico and forecast that it could reach Texas. The disease was occurring in Mexico as close as Tampico, and attempts were made to encourage the Mexicans to vaccinate all their horses in northeastern Mexico, but there was no authority to act and the vaccinations were not done. The Department had emergency headquarters set up in Texas before the first case occurred in the United States. Vaccination of horses in Texas was begun before any cases had occurred in this country, but it was not compulsory and it was done at the owner's expense. The Secretary of Agriculture had to declare an emergency before funds could be made available for a full-scale control program.

The Department of Defense developed the VEE vaccine for use in humans, but the vaccine had not been proven effective by controlled tests in equines to prove that the virus could not be increased in virulence by passage through horses. It has now been proven that the virulence is not changed by such procedure. As the outbreak moved across Mexico, on several occasions the Mexican authorities moved in and vaccinated broad bands ahead of the disease. Unfortunately, the disease immediately appeared just beyond the vaccinated areas. The Mexicans were suspicious that the vaccine itself had caused the spread, but this has also been proven untrue. In Texas, the USDA vaccinated a large enough area so that there was no chance that the virus could hop over the vaccinated area.

PANEL: U. S. ARMY ACTIVITIES IN THE 1971 VENEZUELAN EQUINE ENCEPHALITIS OUTBREAK IN MEXICO AND TEXAS

Bruce F. Eldridge[1], Bernard A. Schiefer[1] and William G. Pearson[2]

INTRODUCTION.–The history of the spread of epidemic Venezuelan equine encephalitis (VEE), presumably from a focus in Ecuador, to northeastern Mexico and southern Texas has been well documented (Sudia and Newhouse, 1971). During the summer of 1971 individuals of government agencies at various levels from local to federal contributed significantly to efforts to curb the spread of the disease. U. S. Army personnel were involved in several aspects of this effort, primarily at the request of the U. S. Department of Agriculture (USDA) and the U. S. Public Health Service (USPHS). Twenty entomologists and ten technicians were engaged in the field on a full-time basis during the height of the epidemic and were supported by many other entomologists, virologists, veterinarians and other scientific and technical personnel in laboratories and administrative offices at several Army installations. They were joined in most of these activities by entomologists and other personnel of the U. S. Air Force (USAF).

One of the most significant Army contributions was the development, testing, and production of an attenuated VEE vaccine (TC-83) at the U. S. Army Medical Research Institute of Infectious Diseases, Ft. Detrick, Maryland (USAMRIID). The vaccine had been developed for protection of laboratory personnel working with VEE and had been produced by the serial passage of the Trinidad strain of VEE in cell culture (Spertzel and Kahn 1971). After the diagnosis of VEE in Texas, the vaccine was released to the USDA, whereupon nearly three million horses were eventually inoculated (Ralph C. Knowles, D. V. M., Animal Health Division, USDA; personal communication).

In response to a request by the USPHS, a team of Army entomologists was sent to southern Texas to conduct pre-post-spray surveys of mosquitoes to evaluate the efficacy of the massive aerial spray program conducted cooperatively by the USDA and the USAF. This team was coordinated by the U. S. Army Environmental Hygiene Agency, Edgewood Arsenal, Maryland, and consisted of entomologists of that agency plus USAF entomologists.

From the standpoint of personnel involved, the largest Army effort was the surveillance of a four-state area for a 30-day period to determine whether local mosquito populations were infected with VEE. The remainder of this paper will describe the results of this surveillance.

PLANNING AND ORGANIZATION.–On July 22, 1971 the Surgeon General, USPHS, asked the Secretary of Defense for support in the form of ten 2-man surveillance teams each consisting of an entomologist and a preventive medicine specialist plus necessary laboratory support. Surveillance was requested in ten large geographic areas in the states of Texas, Oklahoma, Arkansas, and Louisiana (Fig. 1). These areas formed a continuous band surrounding, but outside of the then known VEE epidemic area in southern Texas. The Secretary of Defense designated Department of the Army (DA) executive agent, and the Surgeon General, DA in turn was given responsibility for the mission. Planning and coordination was done by the Health and Environment Directorate, Office of the Surgeon General.

Ten commissioned entomologists (nine Army and one Air Force) were placed on orders from various posts and bases in the U. S. and ten enlisted preventive medicine specialists were drawn from the 485th Preventive Medicine Unit, Ft. Sam Houston, Texas. These individuals formed the ten 2-man field teams. In addition, five entomologists from the Walter Reed Army Institute of Research (WRAIR) and one from the Fifth US Army Medical Laboratory, Southern Area (FUSAML) were employed for supervision and technical guidance, and for the identification and processing of mosquito specimens.

Shipment of specimens from the field teams to FUSAML, which served as a base of operations and where the specimens were identified and pooled, was by Army aviation, utilizing small single-engine planes. After identification and pooling, specimens were sent to USAMRIID, Ft. Detrick, Maryland, where all virus procedures were carried out.

Reports on mosquito biting activity and presumptive virus isolations were sent frequently to the National Center for Disease Control, Atlanta, Georgia.

TRAPPING METHODS.–Surveillance teams trapped six nights per week, sampling five sites each night. Three CDC miniature light traps were used at each site. Various assortments of standard Army traps (6 v. motor) and commerical traps (4 v. motor with and without resistor for 6 v. operation) were used. Each morning, after processing of the previous night's capture, the teams moved on to a different area until six subareas within each large geographic area had been sampled. The cycle was then repeated. Unproductive sites were eliminated. Each team, then, surveyed each of approximately 30 sites four times during the one-month period. The handling of specimens was essentially as outlined in Sudia and Chamberlain (1967). Dry ice as a supplemental attractant was used in all areas initially, but was discontinued in the four eastern areas because of the very large numbers of mosquitoes collected.

RESULTS.–Collections began July 28, six days after the date of the request for assistance from the Surgeon General. During the next 30 days, 501,992 female mosquitoes were collected. These mosquitoes were identified, pooled, and packed at FUSAML for shipment to USAMRIID. This operation required approximately 1700 man-hours of effort, and was not completed until 20 days after the final collection was made. Thirteen thousand one hundred ninety three mosquito pools were sent to USAMRIID (Table 1). From these, 29 virus isolates were obtained (Table 2).

The geographic distribution of the virus isolates is shown in Fig. 2. Twenty-six of these isolates were western equine

[1]Department of Entomology, Walter Reed Army Institute of Research, Washington, D. C.

[2]Office of the Surgeon General, Department of the Army, Washington, D. C.

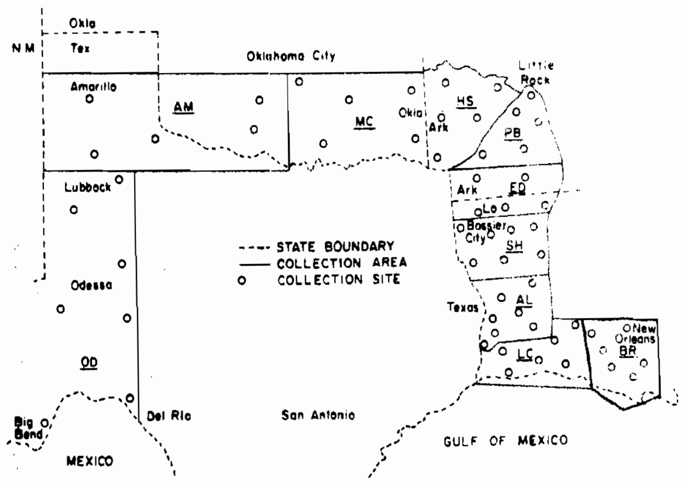

Figure 1.–Ten surveillance areas in southwestern United States, 1971, showing 2-letter code designations used in Table 2.

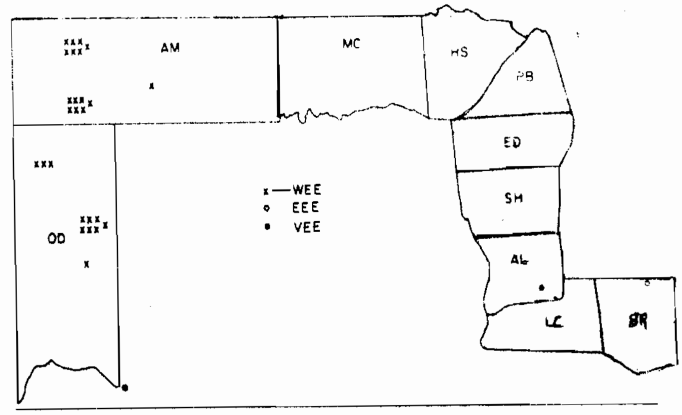

Figure 2.–Geographic distribution of arbovirus isolates from mosquitoes, 1971.

Table 1.–Species collected, all areas, July 28 – August 26, 1971.

SPECIES	NUMBER SPECIMENS	NUMBER POOLS Total	Positive
Psorophora confinnis	183,864	2,466	2
Culex salinarius	107,845	1,700	
Culex (Melanoconion) spp.	25,491	1,015	
Anopheles crucians-bradleyi	21,586	663	
Psorophora cyanescens	15,305	297	
Psorophora ferox	14,790	420	
Aedes vexans	13,600	829	
Aedes taeniorhynchus	12,956	271	
Culex tarsalis	12,808	321	22
Aedes sollicitans	12,455	318	
Psorophora signipennis	9,734	213	
Aedes nigromaculis	9,206	204	
Aedes atlanticus-tormentor	8,341	329	
Anopheles quadrimaculatus	7,529	642	
Aedes spp.	5,373	257	
Culex (Culex) spp.	4,756	165	1
Mansonia perturbans	4,492	328	
Aedes fulvus-pallens	4,338	226	
Culicidae spp.	2,770	32	
Uranotaenia lowii	2,447	77	
Psorophora discolor	2,258	188	1
Uranotaenia sapphirina	2,187	173	
Psorophora spp.	2,157	102	
Psorophora ciliata	2,057	311	
Aedes dupreei	1,817	97	
Culex quinquefasciatus	1,474	135	
Aedes thelcter	1,385	65	1
Anopheles punctipennis	1,018	295	
Psorophora horrida	967	64	
Aedes infirmatus	943	107	
Anopheles pseudopunctipennis	661	61	
Aedes trivittatus	627	72	
Aedes dorsalis	627	29	
Psorophora varipes	623	63	
Anopheles spp.	618	33	
Psorophora howardii	535	169	
Uranotaenia syntheta	495	24	
Culex coronator	408	30	
Culex restuans	308	57	
Culiseta melanura	232	37	1
Aedes triseriatus	215	101	
Aedes campestris	120	10	
Aedes atropalpus	99	31	
Culex thriambus	96	23	
Aedes sticticus	91	14	
Anopheles franciscanus	69	34	
Aedes hendersoni	54	25	
Aedes cinereus	26	10	
Aedes canadensis	19	12	
Aedes zoosophus	16	13	
Orthopodomyia spp.	10	10	
Aedes aegypti	8	2	
Culex territans	5	5	
Orthopodomyia signifera	3	3	
Aedes mitchellae	2	2	
Culex nigripalpus	1	1	
Psorophora longipalpis	1	1	
	501,992	13,193	29

encephalitis (WEE) all from sites in western Texas. A single isolate of eastern equine encephalitis (EEE) was obtained from Tangipahoa Parish, Louisiana, and two isolates of Venezuelan equine encephalitis (VEE) were obtained. One of these was from a pool of *Psorophora confinnis* collected August 18, in Valverde County, Texas. This isolate proved to be the epidemic strain of VEE. The other isolate was also from a pool of *Psorophora confinnis*, in this case collected August 10 in Evangeline Parish, Louisiana. This isolate, however, did not kill guinea pigs by peripheral inoculation

Table 2.–Virus Isolates.

DATE	VIRUS	SPECIES	AREA
31 July	WEE	*Culex tarsalis*	OD
2 August	EEE	*Culiseta melanura*	BR
5 August	WEE	*Culex tarsalis*	AM
5 August	WEE	*Culex tarsalis*	AM
5 August	WEE	*Aedes nigromaculis*	AM
7 August	WEE	*Culex tarsalis*	OD
9 August	WEE	*Culex tarsalis*	OD
9 August	WEE	*Culex tarsalis*	OD
10 August	VEE	*Psorophora confinnis*	AL
14 August	WEE	*Culex tarsalis*	OD
16 August	WEE	*Culex tarsalis*	AM
16 August	WEE	*Aedes thelcter*	OD
16 August	WEE	*Culex tarsalis*	OD
16 August	WEE	*Psorophora discolor*	OD
17 August	WEE	*Culex tarsalis*	OD
18 August	VEE	*Psorophora confinnis*	OD
19 August	WEE	*Culex tarsalis*	AM
19 August	WEE	*Culex tarsalis*	AM
19 August	WEE	*Culex tarsalis*	AM
19 August	WEE	*Culex tarsalis*	AM
23 August	WEE	*Culex tarsalis*	OD
23 August	WEE	*Culex tarsalis*	OD
23 August	WEE	*Culex tarsalis*	AM
23 August	WEE	*Culex tarsalis*	AM
23 August	WEE	*Culex tarsalis*	AM
23 August	WEE	*Culex tarsalis*	AM
23 August	WEE	*Culex tarsalis*	AM
23 August	WEE	*Culex tarsalis*	AM
23 August	WEE	*Culex tarsalis*	AM

(Peterson et. al. 1972). As a follow-up to this isolation, Army investigators from WRAIR returned to Evangeline Parish in November 1971 and trapped mosquitoes and rodents for a three-week period. The results of these studies are not available at this time.

DISCUSSION.–WEE is known to be endemic in the irrigated high plains areas of western Texas (Harmston et al. 1956) and the 26 isolates from this area were not, therefore, unexpected. The isolate of EEE, likewise, was from an area from which previous activity of this virus had been reported (Hauser 1948). The isolate of VEE from Valverde County, Texas was from a pool of mosquitoes collected near Del Rio. Confirmed horse cases were also reported from Valverde County (Morbidity and Mortality Weekly Report 20(33): 295.

In contrast to the Valverde County isolate, which was found to be the epidemic strain of virus, the Evangeline Parish, Louisiana isolate is difficult to explain. Since it did not kill guinea pigs by peripheral inoculation and since there was no other evidence of VEE activity in the entire state in 1971, the possibility looms that it was the vaccine (TC-83) strain of VEE. Spertzel and Kahn (1971) concluded that the likelihood of establishing a horse-mosquito transmission cycle with the vaccine strain was extremely low or even absent, based on experimental evidence of virus titers necessary for mosquito infection and virus titers in horses resulting from vaccination. The recovery of virus from a non-blood-engorged mosquito (abdomens of blood-engorged female mosquitoes were routinely dissected off and not included with the pools) would indicate that mosquito infection may occur as a result of vaccination. The date of collection (August 10) coincides, also, with the period of known vaccination activity in Evangeline Parish (F. A. Humphreys, D.V.M., Animal Health Division, USDA; personal communication). This isolated occurence, even if it does represent a case of natural mosquito infection by a vaccinated animal, does not furnish enough information upon which to speculate as to its epidemological significance. It is, however, the first reported instance of such an occurrence in nature, and certainly additional research on the subject is indicated.

SUMMARY.–As a result of requests for assistance by the USDA and the USPHS, U. S. Army and U. S. Air Force personnel became involved in several aspects of the 1971 VEE epidemic in Mexico and Texas. In addition to the development and production of the vaccine used to vaccinate nearly three million equines against the disease, Army personnel were used to conduct pre- and post-spray mosquito surveys to evaluate aerial spraying done by the U. S. Air Force. The largest involvement, in terms of number of people employed, was the 30-day surveillance of mosquitoes in a four-state area comprising a continuous band around the known epidemic area. Over 500,000 mosquitoes were collected and placed in over 13,000 pools for virus isolation. Twenty-nine virus isolates (26 WEE, 1 EEE, and 2 VEE) were obtained. One of the VEE isolates (from Valverde County, Texas) was of the epidemic strain but the other (from Evangeline Parish, Louisiana) did not kill guinea pigs by peripheral inoculation, and may have been due to a mosquito becoming infected from a recently vaccinated horse. This would be the first such occurrence in nature reported.

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PANEL: SOUTHERN CALIFORNIA ACTIVITIES AGAINST VEE

Telford H. Work
University of California
School of Public Health, Los Angeles, California 90024

The seriousness of VEE in human beings has been overlooked. This virus has produced more laboratory infections than any other arbovirus, some terminating fatally. The frequent and prolonged presence in the nasopharynx provides the risk of non-arthropod transmission on close and prolonged contact. To emphasize the dangerous consequences of epidemic VEE, one need only examine the experience of Venezuela and the epizootic of 1962-64. They had an equine vaccination program but it did not stop the epidemic. It has been estimated that in a national population of 8,000,000, as many as 100,000 cases occurred, mostly in children because the adults had been immunized by infections during an epidemic in 1942-43. Of the 100,000 cases, 3,000 may have involved the central nervous system, with possibly 1,500 deaths. It was during this epidemic that the fetal malformations were first observed, attributed to VEE virus infections during the second trimester of pregnancy. A graduate from our arbovirus program at UCLA studied almost 90 cases in the Rio Grande Valley in 1971, and a significant number had central nervous system involvement.

Mexican authorities have attempted to inhibit transmission of the VEE virus since its crossing into Chiapas in 1969, by ringing the epizootic area with equine vaccinations. The fact that it leap-frogged out of there into other areas, and passed through a large endemic area south of Vera Cruz, suggests that there are mechanisms other than the classic equine-mosquito transmission that support movement of the virus.

By the end of October 1972, there was reported activity of VEE from the Casa Grande south of the New Mexico-Arizona border, and reports from Mazatlan also indicated that it reached the Pacific Coast. In each of the winter seasons since 1969, activity subsided only to appear again in the following spring.

Studies by UCLA staff have demonstrated that there is virus transmission of some form of arbovirus every month of the year in the Imperial Valley. In 1971, western equine encephalitis was obtained from mosquito pools in April, May, June, and July. The staff has reached the following opinions relative to VEE:

1. There is no evidence that VEE will not resume epizootic activity after the winter season, nor that it will cease its northwestward movement.
2. The equine sentinels for appearance of this virus have been virtually eliminated by vaccination in California.
3. The Imperial Valley supports a varied mosquito population that annually transmits California encephalitis virus by *Culiseta inornata* in the winter and St. Louis and western equine encephalitis viruses by *Culex tarsalis* in the warmer months of the year. This indicates a variety of vertebrate reservoirs that could receive and support VEE virus transmission should it be introduced.
4. In the area where the Alamo River passes under the All American Canal is a habitat which supports a population of *Psorophora confinnis* mosquitoes, accepted as one of the most commonly infected mosquito species in the 1971 epizootic in Texas.
5. With California's equine sentinels virtually eliminated by last summer's vaccination program, surveillance must fall back on attempts to isolate the virus from mosquitoes, on reports of viremia, and on detection of antibodies in man and other exposed vertebrates.
6. Every effort must be made to monitor continuously all systems in the most effective way in order to detect the appearance of VEE virus which would signal the need for a vector control campaign.

PANEL: SURVEILLANCE FOR VENEZUELAN EQUINE ENCEPHALITIS VIRUS AND OTHER ARTHROPOD–BORNE[1] VIRUSES BY THE CALIFORNIA STATE DEPARTMENT OF PUBLIC HEALTH, 1971

Richard W. Emmons[2], Richard F. Peters[3] and George L. Humphrey[4]
California State Department of Public Health
2151 Berkeley Way, Berkeley, California 94704

The advent of Venezuelan equine encephalitis (VEE) on the U. S. scene during the summer of 1971, after its progression northward through Central America and Mexico earlier, generated considerable concern and activity to prevent the further spread of the disease. Although California was not immediately threatened, we had and continue to have sufficient cause for concern. Since there is no evidence that the disease has ever been present in this State, we assume there is universal susceptibility in humans, equines, and other natural hosts. The extensive immunization program for equines begun in 1971, and intensified mosquito control activities, will certainly help prevent the introduction or subsequent spread of VEE, but these special efforts must continue indefinitely until it is clear that there is no longer any danger of introduction or spread.

California, of course, was not caught unprepared, since a strong tradition and organization for surveillance and control of mosquito-transmitted encephalitis has been built up over many years. We appreciate this opportunity to present to the 40th Annual California Mosquito Control Association Conference a brief outline of what the California State Department of Public Health has been doing and will continue to do, working closely with other state, federal, and local agencies, to help prevent VEE as well as to continue the already established surveillance and control program against western (WEE) and St. Louis (SLE) encephalitis.

That the threat from these diseases remains, is illustrated by the listing of human cases during the past two decades shown in Table 1. Though cases have been fewer in recent years, viral activity has persisted and stands ready to again erupt into extensive epidemics should mosquito control falter.

A brief summary of past, present, and proposed future activities relating to arbovirus surveillance and control is shown in Table 2 and need not be elaborated upon except to mention that special effort was made to educate the medical community on the features of VEE which differed diagnostically, epidemiologically, or in terms of prevention and control from those of WEE or SLE. The results of these surveillance efforts during 1971 are summarized briefly below and in the remainder of the tables.

There were 60,084 mosquitoes (1,759 pools) tested in the general virus survey and 461 mosquitoes (25 pools) tested in a special survey. These are shown by species, county, and month of collection in Tables 3 and 4.

There were 65 viral isolates from the mosquitoes, as shown in Table 5, including 20 Turlock, 16 western encephalitis, 6 St. Louis encephalitis, 2 California encephalitis (CE) group, and 21 unidentified viruses. The latter have been shown not to be Turlock, WEE, SLE, or CE viruses; further attempts at characterization are in progress.

Table 1.–Human cases of arthropod-borne[a] encephalitis (California, 1950-70).

Year	Total	Western	St. Louis	Deaths
1950	157	88	69	2 - (1 WEE, 1 SLE)
1951	55	22	33	
1952	420	375	45	10 - (9 WEE, 1 SLE)
1953	36	14	22	1 - (SLE)
1954	121	22	99	2 - (SLE)
1955	9	6	3	
1956	21	14	7	
1957	26	3	23	1 - (WEE
1958	53	37	16	
1959	42	2	40	1 - (SLE)
1960	13	1	12	
1961	10	2	8	1 - (WEE)
1962	21	5	16	1 - (SLE)
1963	15	3	12	
1964	12	10	2	
1965	10	9	1	
1966	17	9	8	
1967	15	7	8	
1968	15	11	4	
1969	5		5	

[a]All cases of arthropod-borne encephalitis are laboratory confirmed.

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[2]Viral and Rickettsial Disease Laboratory.

[3]Bureau of Vector Control and Solid Waste Management.

[4]Veterinary Section.

Table 2.–Arthropod-borne virus encephalitis surveillance and control activities in California, 1971[a]

	SURVEILLANCE ACTIVITIES	CONTROL ACTIVITIES
Prior to 1971	Water conditions, temperature Mosquito larvae, abundance Mosquito adults, abundance Mosquito testing for virus Human illness (clinical, virus isolation, serology) Equine illness (clinical, virus isolation, serology) Sentinel chickens Wildlife surveys (virus isolation, serology)	Water management Mosquito larviciding Mosquito adulticiding Biological control of mosquitoes Personal prophylaxis-mosquitoes WEE vaccination (equines) Mosquito insecticide resistance studies Other research on control methods
Added in 1971	Expansion of above activities Special effort on VEE: education of lay and medical community; additional coordination of inter-departmental activities VEE virus added to routine diagnostic tests (equines, humans)	Expansion of above activities VEE vaccination (equines) Equine quarantine
Future Efforts	Increase of above efforts Improve diagnostic laboratory methods Identify potential VEE vectors Arbovirus antibody prevalence in a sample survey of human population in California Determine if VEE vaccine virus can spread to environment or revert to virulence ment or revert to virulence Determine virus pathogenesis: host viremia or other routes of excretion Cost-benefit study Attempt to obtain adequate research funds	Additional emphasis on ecologically sound mosquito control Maintain VEE immunization Increase of above efforts Vaccinate other domestic animals? Specific control of important amplifying wildlife hosts? Develop safer, more effective vaccine Cost-benefit study Attempt to obtain adequate funds

[a]In addition to the California State Department of Public Health efforts, valuable information obtained through the efforts of non-Department-studies, mosquito abundance surveys, equine illness surveillance. Control activities also include many of these agencies. Cooperating agencies include: mosquito abatement agencies; California Department of Agriculture; local health departments; the Federal Center for Disease Control; University of California, Schools of Public Health at Berkeley (Dr. W. C. Reeves) and Los Angeles (Dr. T. H. Work); University of California, Davis (Agriculture Extension Service); and private physicians and veterinarians.

Table 3.–Numbers of mosquitoes and other Diptera tested in suckling mice by species and month, California, 1971 Viral and Rickettsial Disease Laboratory.[a]

SPECIES	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
Culex								
tarsalis	1,603 (49)	9,951 (242)	20,699 (479)	6,103 (151)	993 (39)	66 (5)	48 (5)	39,463 (970)
peus	43 (6)	131 (8)	1,243 (41)	242 (15)				1,659 (70)
pipiens	6 (3)	96 (23)	238 (16)	336 (28)	695 (27)	91 (8)	48 (5)	1,510 (110)
erythrothorax	1,313 (28)	296 (24)	211 (11)	2 (2)	24 (6)	137 (13)	61 (4)	2,044 (88)
Culiseta								
inornata	9 (3)	52 (4)	105 (3)	18 (4)	29 (13)	48 (7)	10 (5)	271 (39)
incidens		18 (2)	108 (4)	29 (1)				155 (7)
Aedes								
melanimon	657 (18)	573 (21)	1,258 (38)	2,275 (53)	22 (4)			4,785 (134)
vexans	403 (10)	1,038 (35)	538 (24)	437 (12)	50 (7)	2 (2)		2,468 (90)
dorsalis		63 (5)	512 (14)	15 (1)	8 (5)			598 (25)
nigromaculis	95 (7)	74 (9)	857 (32)	334 (16)	7 (4)			1,367 (68)
squamiger		155 (4)						155 (4)
unidentified			25 (1)					25 (1)
Anopheles								
freeborni	1 (1)	38 (6)	2,680 (48)	694 (18)	4 (1)			3,417 (74)
franciscanus	1 (1)	203 (13)	31 (3)	1 (1)	2 (2)	1 (1)		239 (21)
punctipennis	8 (2)	17 (2)	69 (3)					94 (7)
Psorophora								
confinnis		22 (3)	307 (14)		871 (22)			1,200 (39)
Mansonia								
perturbans			13 (3)					13 (3)
Culicoides								
occidentalis			500 (5)					500 (5)
unidentified			25 (1)	28 (1)				53 (2)
Stomoxys			68 (2)					68 (2)
TOTAL	4,139 (128)	12,727 (401)	29,487 (742)	10,514 (303)	2,705 (130)	345 (36)	167 (19)	60,084 (1,759)

[a]Total mosquitoes (pools) tested in suckling mice.

Note: An additional 461 mosquitoes (25 pools) from Sutter County during September were tested. These mosquitoes were collected as a special study of VEE-vaccinated equines by the University of California, Davis: *Anopheles freeborni* (437 in 16 pools); *Culex tarsalis* (19 in 5 pools); *Anopheles franciscanus* (2 in 2 pools); *Aedes melanimon* (2 in 1 pool); and *Culex peus* (1 in 1 pool).

Table 4.–Numbers of mosquitoes and other Diptera tested in suckling mice by county and month, California, 1971, Viral and Rickettsial Disease Laboratory.[a]

COUNTY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
Colusa	533 (12)	916 (19)	6,796 (133)	1,559 (35)				9,804 (199)
Contra Costa	102 (3)		450 (18)					552 (21)
Fresno	2 (1)	11 (4)	312 (13)	291 (16)	28 (7)			644 (41)
Glenn				92 (2)				92 (2)
Imperial	233 (5)	2,153 (86)	157 (5)		1,825 (74)	214 (20)	119 (12)	4,701 (202)
Kern	23 (6)	182 (10)	39 (6)	147 (10)	109 (11)			500 (43)
Kings			179 (7)					179 (7)
Lake			515 (6)					515 (6)
Los Angeles			68 (2)					68 (2)
Madera	16 (8)	523 (17)	878 (22)	559 (22)				1,976 (69)
Marin			25 (1)					25 (1)
Mendocino				13 (1)				13 (1)
Merced	1,230 (32)	1,043 (30)	1,688 (43)	3,540 (88)	501 (22)			8,002 (215)
Placer		808 (19)	1,243 (36)	491 (20)				2,542 (75)
Riverside	1,727 (49)	579 (35)	230 (6)					2,536 (90)
Sacramento			806 (24)	75 (2)				881 (26)
San Bernardino			215 (25)					215 (25)
San Diego		2,126 (68)		143 (8)		90 (7)		2,359 (83)
Shasta			2,927 (63)					2,927 (63)
Siskiyou			2,824 (63)					2,824 (63)
Solano			115 (5)					115 (5)
Sonoma			85 (4)	60 (3)				145 (7)
Stanislaus	243 (8)	660 (25)	1,666 (53)	1,458 (45)				4,027 (131)
Sutter		889 (18)	1,814 (40)	5 (1)				2,708 (59)
Tehama		1,146 (29)	2,065 (51)					3,211 (80)
Tulare	30 (4)	216 (6)	2,012 (55)	87 (9)				2,345 (74)
Yolo		1,456 (33)	2,324 (47)	1,994 (41)				5,774 (121)
Arizona		19 (2)	54 (14)		242 (16)	41 (9)	48 (7)	404 (48)
TOTAL	4,139 (128)	12,727 (401)	29,487 (742)	10,514 (303)	2,705 (130)	345 (36)	167 (19)	60,084 (1,759)

[a]Total mosquitoes (pools) tested in suckling mice.

Note: An additional 461 mosquitoes (25 pools) from Sutter County during September were tested. These were collected as a special study of VEE-vaccinated equines by the University of California, Davis: *Anopheles freeborni* (437 in 16 pools); *Culex tarsalis* (19 in 5 pools); *Anopheles franciscanus* (2 in 2 pools); *Aedes melanimon* (2 in 1 pool); and *Culex peus* (1 in 1 pool).

Table 5.–Viral isolates from mosquitoes tested in the Viral and Rickettsial Disease Laboratory, California State Department of Public Health, 1971.*

County	June	July	August	September
Colusa		(1)Unid.	(1)CE group	(2)Unid.‡
			(4)SLE	(1)WEE ¢
			(4)WEE@	
Glenn			(1)Unid.	
Imperial	(1)WEE	(1)Tur		
		(7)WEE		
Madera			(2)Unid.‡	
Placer			(1)Unid.	
Sacramento			(2)Tur**	
San Diego		(4)Tur***		(1)SLE
Shasta			(4)Tur	
Siskiyou			(1)WEE	
Stanislaus		(6)Unid.	(2)Tur**	
		(2)Tur	(4)Unid.	
Sutter		(2)Unid.	(1)Tur	
		(2)Tur	(1)SLE	
Tulare			(1)CE group ****	
Tehama		(1)Unid.	(1)Tur**	
		(1)Tur	(2)WEE	
Yolo			(1)Unid.	
TOTAL:	(21)Unid	(1)WEE	(10)Unid.	
(21)Unid	(1)WEE	(10)Unid.	(10)Tur	(1)WEE
(20)Tur		(10)Tur	(7)WEE	(1)SLE
(16)WEE		(7)WEE	(5)SLE	(2)Unid.
(6)SLE			(2)CEgroup	
(2)CE			(9)Unid.	

*All isolates from *Culex tarsalis* unless otherwise noted.

**1 Turlock virus from *Culex peus;*

***1 Turlock virus from *Anopheles franciscanus.*

@2 WEE virsuses from *Aedes melanimon;*

¢1 WEE virus from *Aedes melanimon.*

‡1 Unidentified virus from *Aedes melanimon.*

****1 CE group virus from *Aedes nigromaculis.*

Additional isolates of WEE, SLE, Turlock, CE, and Unidentified viruses were made by Drs. W. C. Reeves and J. Hardy (Butte and Glenn Counties) and Dr. T. Work (Imperial County) in special research programs, in cooperation with this program.

There were 620 ill persons tested for arboviruses serologically (WEE, SLE, CE, VEE) during 1971, including 16 individuals especially suspect for VEE because of having febrile illness following recent exposure to mosquitoes in epidemic areas of Mexico or Texas. Only one case of infection with epidemic VEE was found, involving an entomologist working in an epidemic area of Mexico. There were three confirmed human cases of western encephalitis from endemic areas of the Central Valley, two confirmed cases of St. Louis encephalitis (proven serologically) and one possible case of St. Louis encephalitis (that exhibited suggestive illness, but unusually late onset and could not be confirmed serologically) (Table 6).

Blood samples from 88 suspect cases (out of a total of 145 reported to the Department) were tested serologically from 27 counties in the state during 1971. There were 16 positive or presumptive positive cases of WEE in ten counties between June and September (Tables 7 and 8). Blood or tissue samples from 79 equines in total were tested for virus by inoculation into suckling mice. No isolations of WEE or epidemic VEE virus were made, but there were six isolations of VEE virus (vaccine strain) made from blood or tissues of recently vaccinated equines (Table 9).

There were 195 tissue specimens (brain tissue predominantly) from various wildlife species which were sent to the laboratory for rabies tests, but were also tested in suckling mice for arboviruses. One isolate of lymphocytic choriomeningitis virus was made from a house mouse (*Mus musculus*), and six isolates of Rio Bravo virus were made from Mexican free-tailed bats (*Tadarida brasiliensis mexicana*) collected in a special research project by Dr. James L. Hardy, School of Public Health, U. C., Berkeley (Table 10).

Future surveillance and control efforts (Table 2) will include those already in effect prior to and during 1971, and these will be expanded appropriately if sources of funding and other support can be found. Even greater emphasis should be placed on achieving ecologically sound mosquito control methods, and on developing more sensitive, economical, and useful surveillance methods to detect virus activity in vector, wildlife, and domestic animal host populations.

ACKNOWLEDGMENTS.–The assistance and cooperation of many staff members of the Viral and Rickettsial Disease Laboratory, the Bureau of Communicable Disease Control, the Veterinary Section, and the Bureau of Vector Control and Solid Waste Management of the State Department of Public Health, as well as of other local, state and federal agencies, in carrying out the program are gratefully acknowledged. Special recognition is made of the contributions of Mr. G. Grodhaus, Dr. D. Cappucci, and Mr. D. Dondero.

Table 6.–Human cases of Western Encephalitis and St. Louis Encephalitis in California during 1971.

Identification and presumed exposure	Clinical course	Antigen	Antibody titers: Acute	Convalescent	
			Oct/8/71	Oct/26/71	Dec/13/71
1. S.C., 31, Female Sacramento, Sacramento, County	Sept/29/71; encephalitis; recovery but prolonged weakness	SLE-CF	<1:8	1:8	1:32
		SLE-NT	0.8	2.0	2.8
		SLE-FA	1:2048	1:8192	1:16,384
		SLE-HAI	1:80	1:80	1:40
			Oct/5/71	Oct/19/71	
2. G.V., 33, Male Sacramento, Sacramento County	Oct/1/71; meningo-encephalitis; complete recovery	WEE-CF	<1:8	1:32*	
		WEE-FA	<1:8	1:128	
		WEE-HAI	1:20	≥1:160**	
			Oct/12/71	Oct/29/71	
3. P.H., 11, Male Butte City, Glenn County	Oct/6/71; meningitis, complete recovery	WEE-CF	<1:8	≥1:128*	
		WEE-FA	1:128	1:1024	
		WEE-HAI	≥1:160	≥1:160**	
			Nov/1/71	Feb/7/72	
4. L.J., 52, Male Cloverdale, Sonoma County; exposure?	Oct/14/71; meningo-encephalitis, complete recovery	SLE-CF	≥1:256	1:64	
		SLE-NT	3.7	3.4	
		SLE-FA	1:1024	1:256	
		SLE-HAI	1:320	1:80	
			Nov/3/71	Nov/15/71	
5. F.M., 11, Male Live Oak, Sutter County	Oct/28/71; encephalitis, complete recovery	WEE-CF	<1:8	1:64*	
		WEE-FA	1:64	1:128	
		WEE-NT	2.7	4.3	
		WEE-HAI	≥1:160	≥1:160**	
			Nov/18/71	Dec/4/71	Jan/6/72
6. V. W., 68, Male*** Stockton	Nov/14/71; encephalitis, with recovery	SLE-CF	1:64	1:64	1:64
		SLE-HAI	1:320	1:320	1:320
		SLE-FA	1:4096	1:4096	1:4096
		SLE-NT	3.0	3.0	3.6

*CF titer for VEE virus

*CF titer for VEE virus <1:8

**HAI titer for VEE virus <1:10

***Suspect case only; could not be proven serologically.

CF - complement fixing antibody titer.
FA - indirect fluorescent antibody titer.
HAI - hemagglutination-inhibition antibody titer.
NT - neutralization test antibody titer (neutralizing index).

Table 7.–Positive and presumptive positive cases of Western Encephalitis in equines, by county and month, for California, 1971.

COUNTY	MONTH OF ONSET				
	Total	June	July	August	Sept.
TOTAL	16	2	1	8	5
Butte	2			2	
Fresno	1	1			
Glenn	5		1	2	2
Imperial	1	1			
Sacramento	1				1
San Joaquin	1			1	
Shasta	2			2	
Stanislaus	1				1
Tehama	1			1	
Yuba	1				1

Footnotes for Table 8. ↓

*May represent response to vaccination, but clinical illness consistent with encephalitis.

**May represent previous infection or immunization. Immunization with VEE vaccine may boost pre-existing WEE antibody titer or may induce cross-reacting WEE antibody, sometimes to a higher titer than for VEE virus.

This summary represents a minimum of the cases which may have occurred. Numerous suspect cases could not be properly tested because of inadequacy of the specimens.

Table 8.–Positive and presumptive positive cases of Western Encephalitis in equines, California, 1971.

County & Identity	Age & Sex	Onset	Vaccine	WEE SEROLOGY Date	WEE SEROLOGY CF	WEE SEROLOGY HAI	VEE SEROLOGY CF	VEE SEROLOGY HAI	Result
1. G. L., Sanger Fresno	3 yr. F	27 June	WEE 27 June	6/27	<1:8	<1:10		<1:10	PRES*
				7/9	1:32	1:160		<1:10	
2. T.H., E. Centro, Imperial	11 yr. G	30 June	?	7/1	1:32	1:160			PRES**
				7/22	1:64	1:160			
				8/13	1:32	1:160			
3. W. G., Orland, Glenn	1 yr. F	26 July	none	7/28	<1:16	1:160		<1:10	POS
				8/16	1:32	1:40	<1:8	<1:10	
4. J.B., Chico, Butte	15 mo. F q	1 Aug	none	8/1	<1:16	1:160		<1:10	POS
				8/19	1:128	1:160	<1:8	<1:10	
5. J. M., Chico, Butte	2 yr. F	1 Aug	WEE 28-30 June	8/1	<1:8	1:160		<1:10	PRES*
				8/18	1:256	1:160	<1:8	<1:10	
6. S. B., Cottonwood, Shasta		8 Aug	none	8/13	1:128	≥1:160	<1:8	<1:10	PRES
				8/30	1:64	≥1:160	<1:8	<1:10	
				9/29	1:32	1:160	<1:8	<1:10	
7. E.L.N., Gerber Tehama	16 mo M	10 Aug	none	8/12	1:8	1:160	<1:8	<1:10	POS
				9/21	1:64	1:160	<1:8	<1:10	
					1:32		<1:8		
8. B. S., Orland, Glenn	1 yr. ?	14 Aug fatal	none	8/14	1:64	>1:160		<1:10	PRES**
				8/28	1:64	>1:160	<1:8	<1:10	
9. C.A.L., Orland, Glenn	2 yr ?	19 Aug	none	8/20	1:32	>1:32	<1:8	<1:10	PRES**
10. C.T.P., Lockeford, S. Joaquin	3 yr. G	23 Aug euthanized	none	8/25	1:64	>1:160	<1:8	1:20	PRES**
11. J.P., Cottonwood, Shasta	16 mo. M	24 Aug	VEE Nov ?	8/25	<1:8		<1:8		POS
				11/1	1:32		<1:8		
12. R.H.W., Yuba City	2 yr. G	1 Sept	VEE 1 Sept	9/2	1:160	>1:160	<1:8	1:80	PRES**
				9/23	>1:256	>1:160	1:32	>1:160	
13. G.F., Orland, Glenn	2 yr. F	5 Sept	VEE 28 Aug	9/22	1:128		1:64		PRES**
				10/27	1:32		1:8		
14. L.C., Sacramento, Sacramento	3 yr. G	20 Sept	WEE/EEE 20 Sept	9/22	1:8	1:160	<1:16	<1:10	PRES*
				10/13	1:128	1:160	<1:8	<1:10	
15. E.L., Turlock,	5 yr. F	23 Sept	VEE 15 Sept	9/23	1:64	1:80	<1:16	>1:160	PRES**
16. F.L., Orland, Glenn	16 mo. M	27 Sept	VEE 9 Sept	9/28	>1:256	1:160	1:64	1:160	PRES**
					1:128	1:160	1:32	1:160	

Table 9.—Isolates of Venezuelan equine encephalitis virus (vaccine strain) from vaccinated equines, by the Viral and Rickettsial Disease Laboratory, California State Department of Public Health, 1971.[a]

Equine identi-fication	Age & Sex	Place	Date of VEE vacc.	Onset of Sx and cause	VEE & species	Negative species
T1-3101	4 yr. F	S. Barbara County	9 August	Abortion 17 August	Placenta 17 August	Mare's serum & blood 17 August
T1-3405	Fetus; 16½ cm Crump	Chico, Butte Co.	7 yr. mare vacc. 28 August	Abortion 11 Sept.	Fetal brain 11 Sept.	Fetal kidney, lung, Heart, marrow, bowel, liver, spleen, eyes
T1-3347	8 yr. F	Santa Clara Co.	31 August	4 Sept.; ? Star thistle poisoning (fatal)	blood 5 Sept.	brain, blood, liver, spleen 9 Sept.
T1-3489	5½ mo. F	Turlock, Stanislaus County	11 Sept. (1:8 to 1:32 CF antibody	14 Sept.; vaccine reaction (recovered)	blood 14 Sept.	
T1-3512/3515	4 mo. F	Lodi, San Joaquin (Modesto)	11 Sept.	16 Sept.; ? vaccine reaction; encephalomyelitis; pneumonia, peritonitis	lung/spleen 18 Sept.	Blood, liver, pancreas, brain 18 Sept.
T1-3623/3626	6 yr.	San Mateo County (U.C., Davis)	20 Sept.	23 Sept.; fatal illness	lung/spleen 23 Sept.	brain, blood, kidney, pancreas 23 Sept.

[a]In addition to above, four other equine fetuses, aborted following VEE vaccination of the mares, have been submitted for testing, and were negative for VEE virus. Fluorescent antibody staining tests have been inconclusive or negative on tissue tested. It is uncertain as yet whether the vaccine virus has actually caused abortion, or is merely present in blood or tissues of fetuses aborted from other causes.

Table 10.—Arbovirus Isolates from wildlife species, California, 1971, at the Viral and Rickettsial Disease Laboratory, California State Department of Public Health.[a]

Virus	Species	Location and Date	Tissues
LOM	*Mus musculus* V1-46 (sick)	712 28th Street (Brausgh) Richmond, Contra Costa Co. 23/April/71	brain
Rio Bravo[b]	*Tadaria mexicana* (normal)	Llano Seco Ranch, Butte County; 14/June/71	brain and organ pool[c]
Rio Bravo	*Tadarida mexicana* (normal)	Llano Seco Ranch, Butte County; 14/June/71	brain and organ pool
Rio Bravo	*Tadarida mexicana* (normal)	Llano Seco Ranch, Butte County; 2/August/71	brain and organ pool
Rio Bravo	*Tadarida mexicana* (normal)	Llano Seco Ranch, Butte County; 2/August/71	brain and organ pool
Rio Bravo	*Tadarida mexicana* (normal)	Llanò Seco Ranch, Butte County; 2/August/71	brain and organ pool

[a]Final results as of 31 December, 1971

[b]All Rio Bravo isolates resulted from a cooperative study with Dr. J. L. Hardy, School of Public Health, University of California, Berkeley.

[c]Organ pools included lung, submaxillary salivary glands, brown fat (interscapular), heart and blood clot, spleen, and kidneys.

PANEL: VETERINARY ASPECTS OF VEE

George L. Crenshaw
University of California
School of Veterinary Medicine, 2004 Haring Hall, Davis, California 95616

There was considerable confusion during 1971 in the VEE program. The concept of quarantining the disease prevailed. Vector control people convinced some people that the disease could be sprayed out of existence. At the behest of the Califonria Bureau of Animal Health, the VEE vaccine was permitted to be used in this State.

The immune status of horses in representative areas of the State was determined, also the previous history of vaccination, exposure to various vectors, especially mosquitoes, and types of management for the horses. About 1,200 horses were sampled, concentrating in southern California. Additional sampling was done in Kern County and in Tehama and Butte counties. The sampling was done prior to vaccination.

When vaccination was started, it progressed much faster than had been anticipated. Credit goes to the State Bureau of Animal Health and to the practicing veterinarians for doing a yeoman job in getting the horse populations vaccinated efficiently and effectively. The frozen vaccine was prepared every day and had to be used within 12 hours. The University had to disseminate what information was available on VEE, particularly to the veterinarians and to the farm advisors. About 393,000 horses received the vaccination. Reports were requested on possible fetal abnormalities since it was unavoidable that some vaccinations were done on pregnant mares. Very few abortions were reported, only eight or ten. Very few adverse effects on the horses were noted, less than 1/10 of 1%.

The biggest segment of the equine populations in California has now been vaccinated. As far as regulations are concerned, horses that are unvaccinated now will have to be vaccinated in 1972 or remain quarantined. A number of questions remain unanswered:

1. Is the vaccine virus transmissible?
2. Can the vaccine virus become involved in a reservoir?
3. Will the vaccine virus regress and become virulent?
4. Will the vaccine truly immunize horses?
5. How many of the vaccinated horses are immunizied?
6. If it does immunize, how long will the horses be protected?

It is not known when foals should be vaccinated. It is not known how long the mother's antibodies will protect the young foal. Some Federal support is now available to assist in the research needed to obtain answers to these questions.

INSECTICIDE SUSCEPTIBILITY OF MOSQUITOES IN CALIFORNIA: ILLUSTRATED DISTRIBUTION OF ORGANOPHOSPHORUS RESISTANCE IN LARVAL *AEDES NIGROMACULIS* AND *CULEX TARSALIS*

Don J. Womeldorf[1], Patricia A. Gillies[2] and Kathleen E. White[3]
California State Department of Public Health
Bureau of Vector Control & Solid Waste Management

In California, DDT resistance in *Aedes nigromaculis*, the irrigated pasture mosquito, has been known since 1949 (Smith 1949). By the early 1950's resistance against DDT and other organochlorine compounds had become widespread in *A. nigromaculis* and in the State's primary vector of St. Louis and western equine encephalitis, *Culex tarsalis* (Bohart and Murray. 1950; Gjullin and Peters 1952). The organophosphorus compounds were then substituted for the organochlorine materials.

Parathion resistance in *A. nigromaculis* was first documented in Kings County in 1958 (Lewallen and Brawley 1958). Within the next few years, parathion and malathion resistance was found in many areas of the Central Valley and methyl parathion resistance also appeared (Brown et. al. 1963). By 1970, parathion resistance had become commonplace, methyl parathion resistance was not far behind, and resistance to fenthion and other organophosphorus compounds had been recorded in several areas of the State (Schaefer and Wilder 1970a) in adults as well as larvae (Ramke et al. 1969; Wilder and Schaefer 1969). Additionally, problems in obtaining adult control with the carbamate propoxur had begun to develop (Womeldorf et al. 1971).

[1]Office Bldg. 9 – 744 P Street, Sacramento California 95814.
[2]5545 East Shields Avenue, Fresno, California 93727.
[3]2151 Berkeley Way, Berkeley, California 94704.

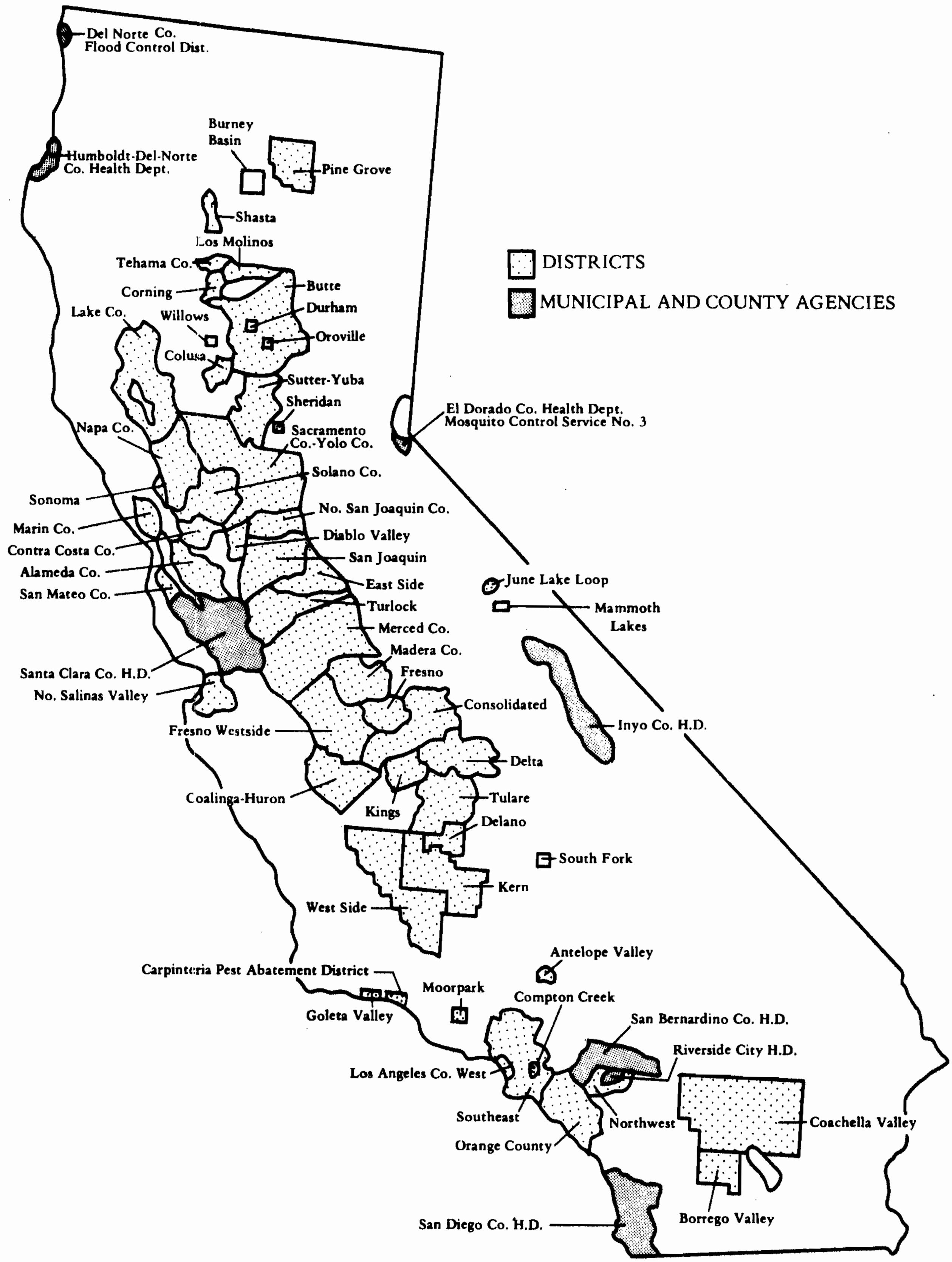

Fig. 1.–California Mosquito Abatement Agencies, 1971.

Fig. 2A.–Documented organophosphorus resistance in *Aedes nigromaculis*, California, 1960.

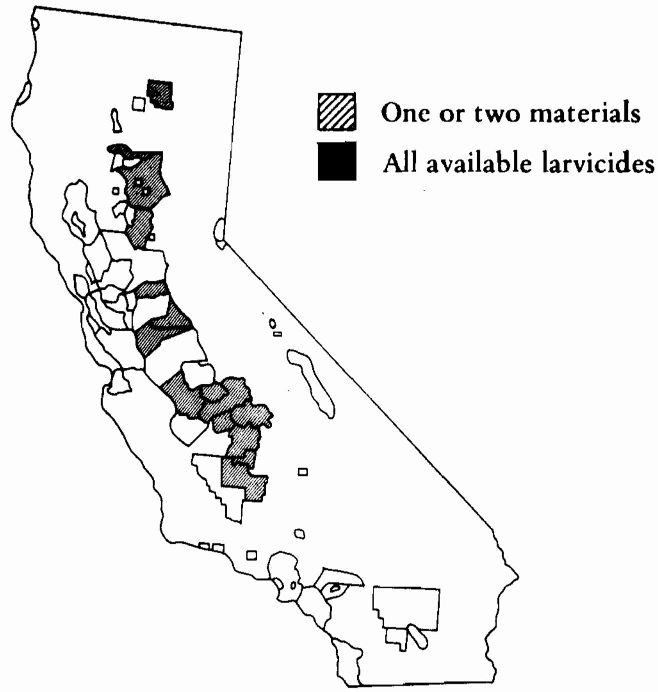

Fig. 2B.–Documented organophosphorus resistance in *Aedes nigromaculis*, California, 1965.

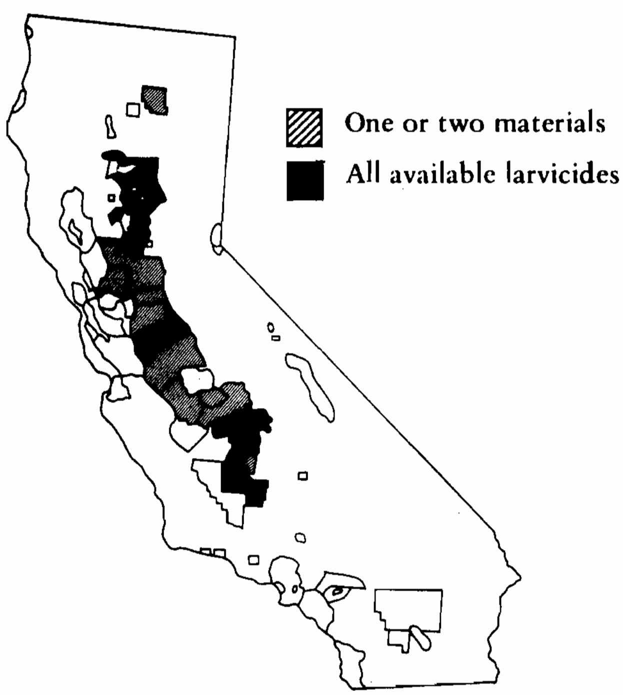

Fig. 2C.–Documented organophosphorus resistance in *Aedes nigromaculis*, California, 1970.

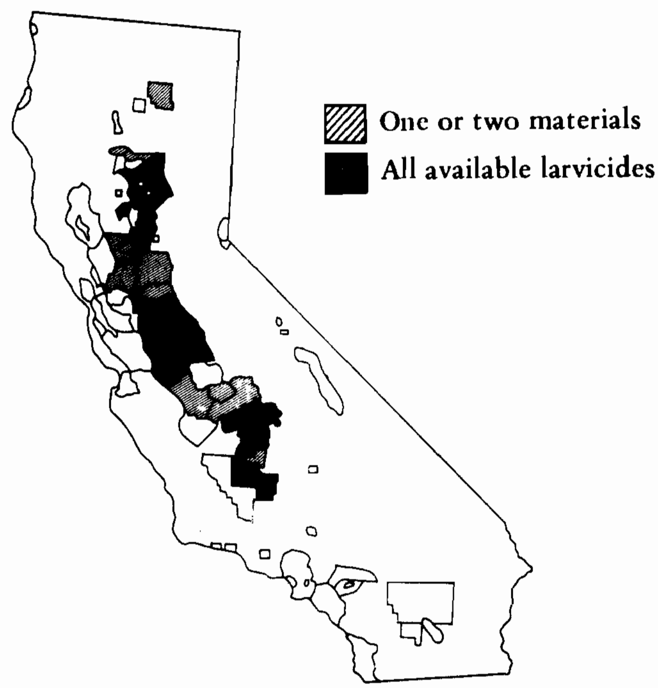

Fig. 2D.–Documented organophosphorus resistance in *Aedes nigromaculis*, California, 1971.

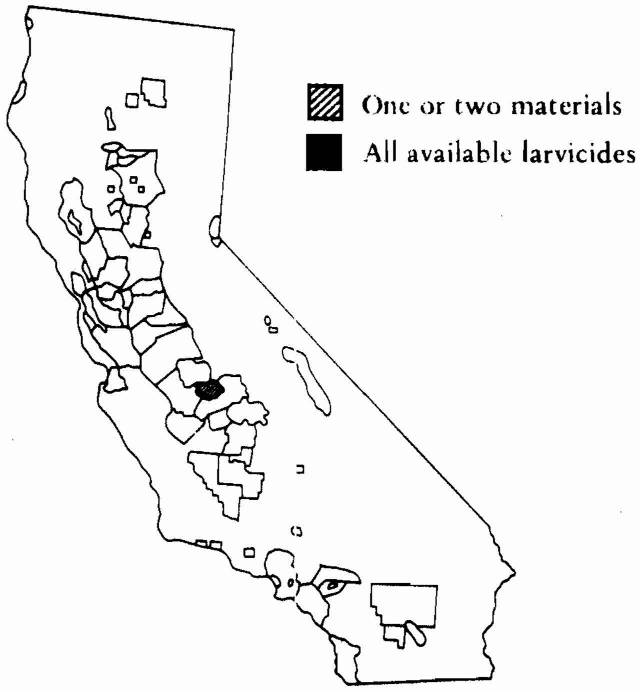

Fig. 3A.—Documented organophosphorus resistance in *Culex tarsalis*, California, 1960.

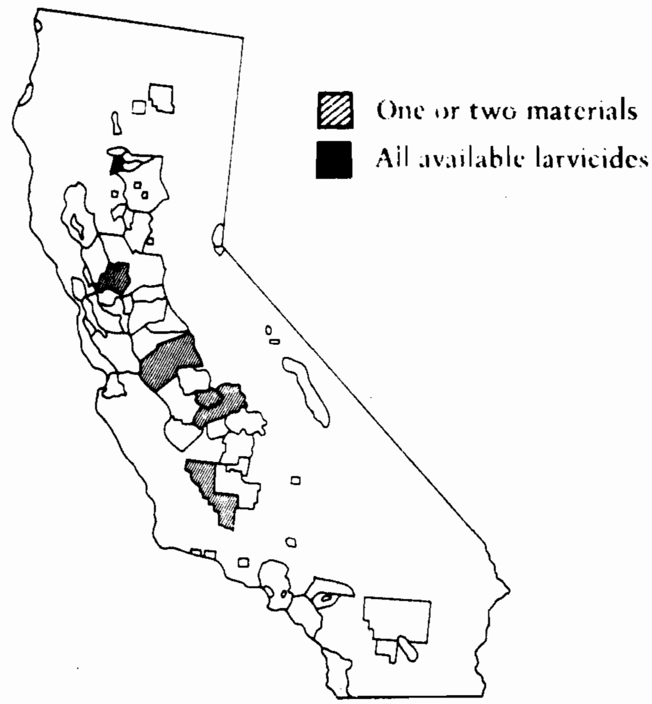

Fig. 3B.—Documented organophosphorus resistance in *Culex tarsalis*, California, 1965.

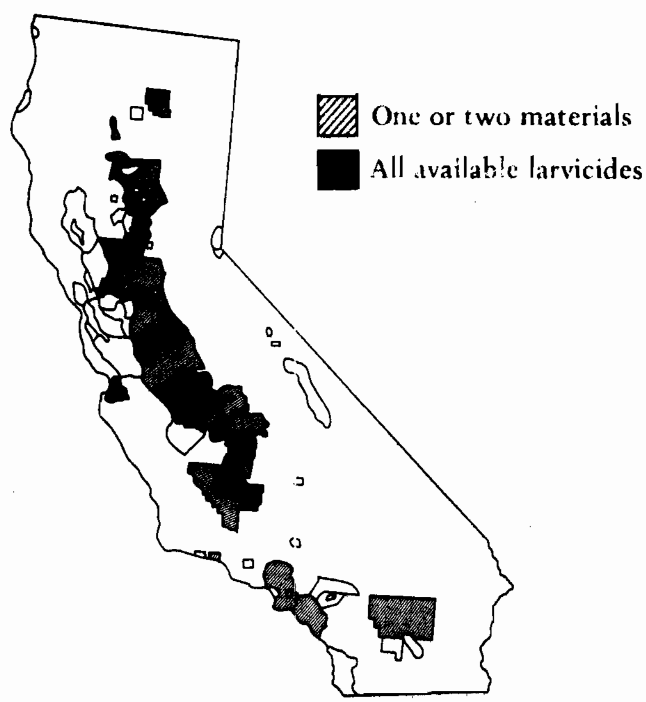

Fig. 3C.—Documented organophosphorus resistance in *Culex tarsalis*, California, 1970.

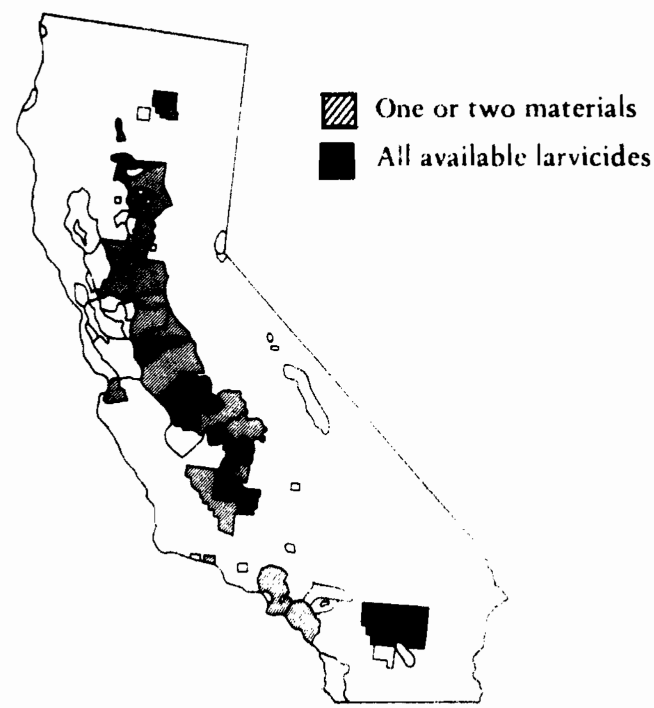

Fig. 3D.—Documented organophosphorus resistance in *Culex tarsalis*, California, 1971.

Malathion resistance in *C. tarsalis* was discovered in 1956 in Fresno County (Gjullin and Isaak 1957). Malathion resistance progressed throughout the Central Valley and is now common in other parts of the State as well. Resistance against all available organophosphorus larvicides became apparent in the San Joaquin Valley in 1969 (Georghiou et al. 1969; Schaefer and Wilder 1970b). Resistance against malathion or against all organophosphorus larvicides is now widespread (Womeldorf et al. 1971).

Figs. 1, 2, and 3 show the location of mosquito control agencies in California, and by mosquito control agency, the occurrence of organophosphorus resistance in *A. nigromaculis* and *C. tarsalis* as documented at the end of the year shown. Inclusion of an agency does not mean that every mosquito population within the agency boundaries has become resistant, but rather that some populations have been shown to be resistant. In the figure, where resistance in *C. tarsalis* to one or two materials is shown, the chemcials are malathion and/or fenthion, while in *A. nigromaculis* they are parathion, methyl parathion, and/or malathion. Resistance against all available organophosphorus larvicides includes those with a use history in California, mainly malathion, EPN, parathion, methyl parathion, fenthion, ABATE® and Dursban.

Instances of resistance in these and other California species is summarized in Table 1. The absence of resistance in *Anopheles freeborni*, the most numerous anopheline species, was discussed by Womeldorf et al. (1970).

Table 1.—Organophosphorus resistance in Californian mosquitoes by species and chemical, 1971.

	Chemical						
Species	malathion	EPN	parathion	methyl parathion	fenthion	ABATE®	Dursban®
Aedes nigromaculis	x	x	x	x	x	x	x
Aedes melanimon			x				
Culex tarsalis	x	x	x	x	x	x	x
Culex pipiens subspp.	x	x	x		x		
Culex peus	x		x	x	x		

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MORTALITY OF CAGED ORGANOPHOSPHORUS–RESISTANT *CULEX TARSALIS* COQUILLETT USING VARIOUS ADULTICIDES APPLIED AS NONTHERMAL AEROSOLS

Patricia A. Gillies[1], Edward M. Fussell[2] and Don J. Womeldorf[3]

INTRODUCTION.–The first organophosphorus insecticide resistance in California *Culex tarsalis* Coquillett was documented in 1956 when Gjullin and Isaak (1957) reported larval resistance to malathion. Since that time, resistance to malathion has become widespread, affecting most controlled areas within the State (Womeldorf et al., 1971). Some scattered instances of resistance to other larvicides were reported, but rarely included more than one chemical in addition to malathion (Womeldorf et al., 1968). Then in 1969, populations cross resistant to other organophosphorus compounds were detected in the southern San Joaquin Valley (Gillies and Womeldorf, 1969; Georghiou et al., 1969). The problem spread and currently involves San Joaquin Valley mosquito control agencies from Stanislaus County in the north to Kern County in the south, as well as one agency in southern California.

C. tarsalis is not only a pest mosquito but is a direct threat to the public health as the primary vector of both St. Louis and western equine encephalitis in California. This species is also a vector of Venezuelan equine encephalomyelitis, although presence of the virus has not yet been detected in California. Should widespread control become necessary in the event of an epidemic, the organophosphorus larvicides would be useless, at legal dosages, in areas afflicted with resistance.

Control is further threatened in that high tolerance in adults has been shown in the laboratory to be related to organophosphorus resistance in larvae (Georghiou et al., 1969; Schaefer and Wilder, 1970), but the effects on control in the field are not yet clear. Attempts to evaluate organophosphorus materials in the field are complicated by the facts that the adults are capable of moving considerable distances, quickly reinfesting treated areas and that field population density is difficult to measure.

The present study was initiated to try to relate mortality in caged populations of organophosphorus resistant *C. tarsalis* with mortality in caged populations of other species about which information on operational resistance is available. Adult mosquitoes, representing various populations, were exposed simultaneously to adulticides dispensed from a nonthermal aerosol generator. The resultant mortality was then compared.

METHODS AND MATERIALS.–Tests were conducted cooperatively between personnel of the California Department of Public Health and the Navy Disease Vector Ecology and Control Center. The test site was a flat, unobstructed stubble field at Skaggs Island, a military reservation in Sonoma County, California. The test materials were applied from a truck-mounted nonthermal aerosol generator. The generator, specifically designed to dispense low volume, high concentrate insecticides, produces a fog dependent upon air movement for dispersal. Capabilities of the generator, including droplet size and distribution pattern, have been discussed by Stains et al. (1969).

Mosquitoes used in the tests were field-collected *Aedes nigromaculis* (Ludlow), *A. melanimon* Dyar and *C. tarsalis* and a laboratory strain of *C. pipiens* L. The field populations were collected as larvae or pupae and were reared to the adult stage in the laboratory. Before taking the mosquitoes to the field, approximately 20 unsexed adults from each test population were transferred to cylindrical cages (2-5/8 x 7 inches) of 16 x 18-inch mesh wire screen. Fruit jar rings with screen inserts closed the ends of the tubes. Sugar water saturated cotton pads were available to the caged mosquitoes prior to testing. For the test, stakes were set out at intervals for a total distance of 5,000 feet downwind from the point of application and the caged adults were suspended from the stakes approximately three feet above ground level. Controls representing each test population were treated in the same manner but were placed upwind where they would not be exposed to the applied insecticide. Any pre-treatment mortality was recorded at the time the cages were placed on stakes. The caged adults were picked up about 30 minutes after each application. The cages were then wrapped individually and placed in plastic bags. Humidity was provided by damp toweling interspersed among the cages. Final post-treatment mortality was assessed at 24 hours.

Insecticides evaluated in the test series were malathion, fenthion, Dursban®, Dowco 214 (methyl Dursban), naled, and propoxur. Commercial formulations were used undiluted or diluted with cottonseed oil as necessary to achieve the desired concentrations.

RESULTS AND DISCUSSION.–The generator output is impossible to determine in terms of rate per acre as the small droplets are carried by the wind as a moving aerosol cloud, and the number of acres covered is dependent upon meteorological conditions during the dispersal. Apparently very little material is lost as ground deposition. Stains et al. (1969), using naled and a fluorescent particle tracer technique, found less than one percent of the aerosol cloud was deposited on the ground and foliage in the first mile. The generator output is best described as the number of ounces dispersed per minute. Both ounces per minute and a nominal dosage rate, designated as pounds per acre, are listed for each test (Table 1). The nominal dosage rate is for comparative purposes only and is based on a forward speed of five mph and the assumption that the entire aerosol cloud was effective within a 5,000 foot swath.

Larvae representing each of the adult populations were tested to determine their susceptibility to the organophosphorus compounds. The results are shown in Table 2. The adults were not tested in the laboratory. Both the Kings and

[1]State Department of Public Health, Bureau of Vector Control and Solid Waste Management, 5545 East Shields Avenue, Fresno, California 93727.

[2]Disease Vector Ecology and Control Center, Naval Air Station, Alameda, California 94501.

[3]State Department of Public Health, Bureau of Vector Control and Solid Waste Management, Office Bldg. 9 – 744 P Street, Sacramento, California 95814.

Table 1.—Application details for adult tests shown in Figures 1-7.

Insecticide	Figure Number	Generator output (oz/min)	Nominal dosage rate (lb/acre)[a]	Wind (mph)	Temperature (degrees F)
Malathion	1	37.8	.012	12-15	75
Fenthion	2	32.0	.0099	10	70
Dursban®	3	36.8	.0115	8-10	70
Dowco® 214 (Methyl Dursban)	4	42.0	.013	8	70
Naled	5	33.0	.010	11	70
Propoxur	6	32.0	.007	8-10	75
Propoxur	7	32.0	.007	7.5	70

[a]Based on the assumption that the entire aerosol cloud was effective within a 5,000-foot swath.

Table 2.—Susceptibility levels (ppm) determined for the larval stage of the test adults.

	Malathion		Parathion		Methyl parathion		Fenthion		Dursban®	
	LC_{50}	LC_{90}	LC_{50}	LC_{90}	LC_{50}	LC_{90}	LC_{50}	LC_{90}	LC_{50}	LC_{90}
Culex pipiens Laboratory colony	.035	.061	.0026	.0040	.0018	.0027	.0026	.0041	.0014	.0019
C. tarsalis Kings MAD							.0057	.032		
C. tarsalis Tulare MAD	.37	2.75	.030	.19	.011	.084	.016	.035	.012	.034
Aedes nigromaculis Turlock MAD			.11	.67	.035	.25	.026	.13	.013	.054
A. melanimon Sutter-Yuba MAD					.0033	.0048	.0015	.0039	.0015	.0050

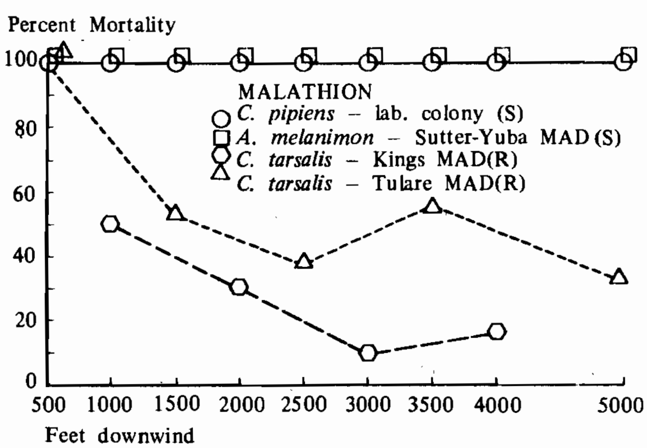

Fig. 1.—Mortality of caged adult mosquitoes at 24 hours after application of malathion from a nonthermal aerosol generator.

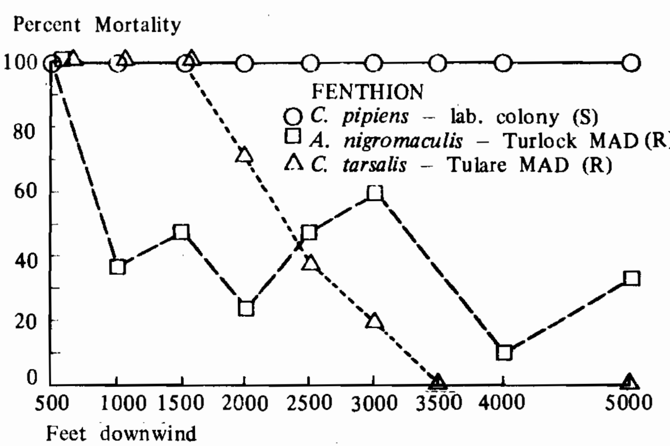

Fig. 2.—Mortality of caged adult mosquitoes at 24 hours after application of fenthion from a nonthermal aerosol generator.

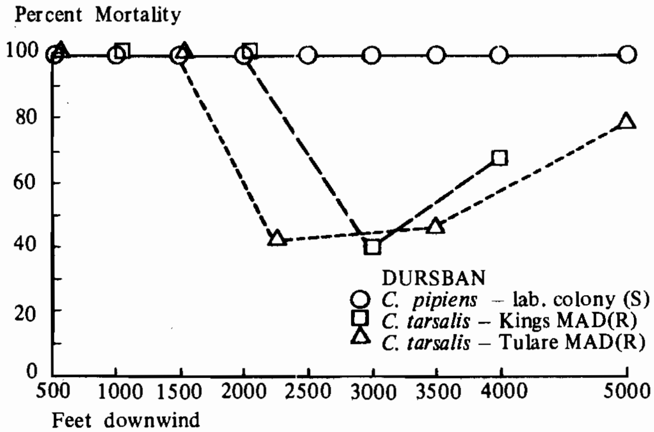

Fig. 3.–Mortality of caged adult mosquitoes at 24 hours after application of Dursban from a nonthermal aerosol generator.

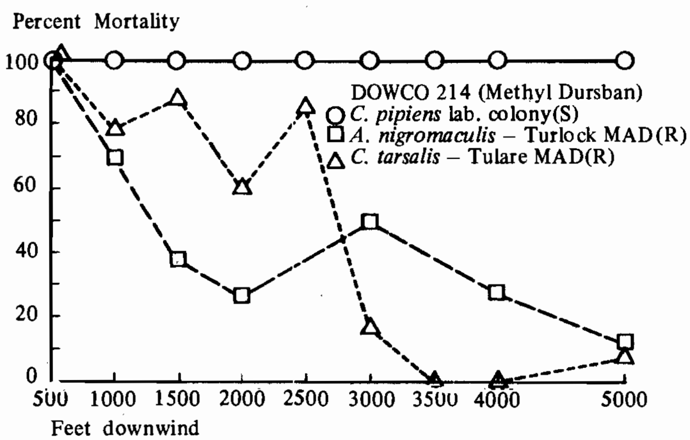

Fig. 4.–Mortality of caged adult mosquitoes at 24 hours after application of Dowco 214 from a nonthermal aerosol generator.

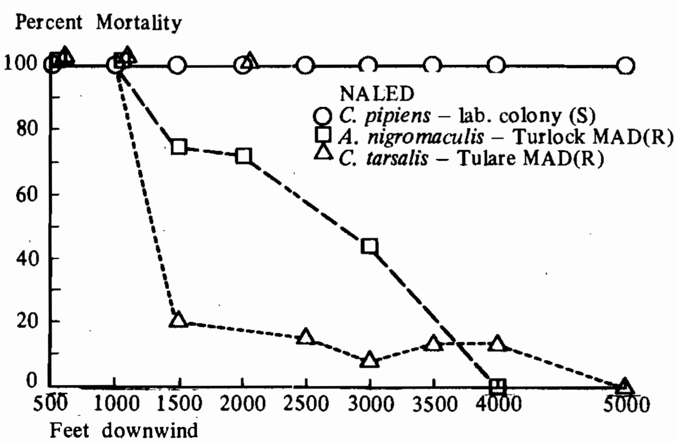

Fig. 5.–Mortality of caged adult mosquitoes at 24 hours after application of naled from a nonthermal aerosol generator.

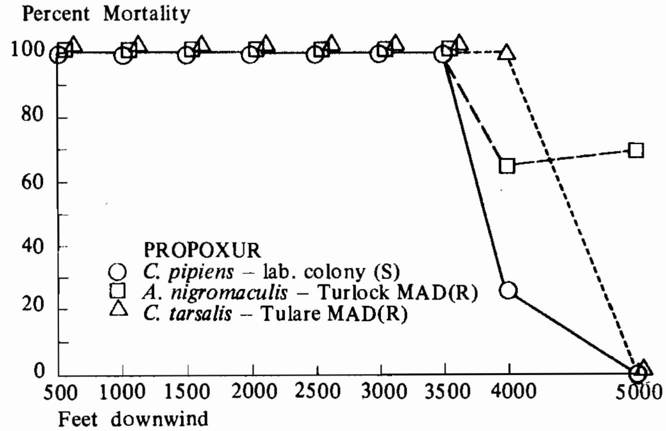

Fig. 6.–Mortality of caged adult mosquitoes at 24 hours after application of propoxur from a nonthermal aerosol generator.

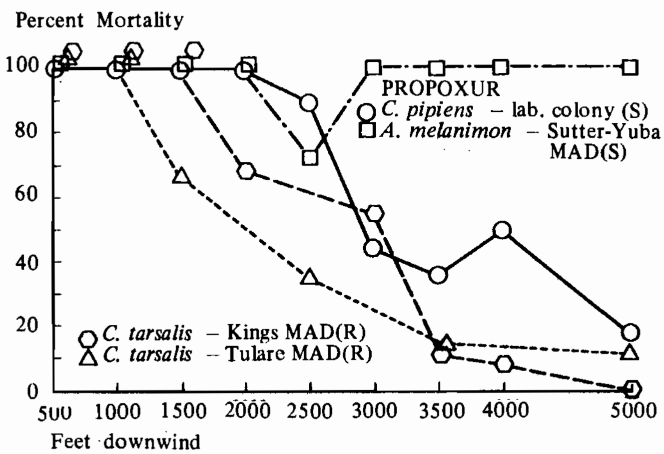

Fig. 7.–Mortality of caged adult mosquitoes at 24 hours after application of propoxur from a nonthermal aerosol generator.

Tulare Mosquito Abatement District populations of *C. tarsalis* are known to be operationally resistant to the organophosphorus larvicides. Georghiou, et al. (1969) and Wilder and Schaefer (1969) demonstrated adult resistance in populations with comparable levels of larval resistance. The *A. nigromaculis* from the Turlock Mosquito Abatement District have a history of larval and adult resistance which has been verified both in the laboratory and in the field. Adulticiding with propoxur is the only currently successful control method. The *A. melanimon* from Sutter-Yuba Mosquito Abatement District and the laboratory strain of *C. pipiens* are susceptible both as larvae and as adults.

Propoxur (Figs. 6 and 7) appeared to be the most promising of the test materials for the control of the resistant *C. tarsalis*. Comparable mortality was achieved against both the resistant species and the susceptible *C. pipiens*. Since it is known that propoxur is the only available adulticide effective for control of highly resistant populations of *A. nigromaculis*, and 100 percent mortality of both the *C. tarsalis* and the *A. nigromaculis* was achieved of the 3,500-foot station, it could be assumed that this material would be as effective against *C. tarsalis* as it is against *A. nigromaculis* (Fig. 6). Womeldorf, et al. (1971) found the larval failure threshold of organophosphorus resistant *A. nigromaculis* to match that for resistant *C. tarsalis*.

Unfortunately, *A. nigromaculis* adults were not available for the second propoxur test (Fig. 7), but again propoxur appeared to be only slightly more toxic to the susceptible *C. pipiens* than to the resistant *C. tarsalis*. In this test, 100 percent mortality of *A. melanimon* was achieved at the 5,000-foot station, perhaps indicating greater susceptibility of this species to propoxur. At the 2,500-foot station, only 73 percent mortality was achieved. The reason for this discrepancy is not known.

One hundred percent mortality of the resistant populations did not extend past the 2,000-foot station for any of the other materials tested, although complete mortality of the susceptible species occurred out to the 5,000-foot station.

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PUBLIC HEALTH PROTECTION CHEMICAL RESISTANCE IN LARVAL *CULEX PIPIENS QUINQUEFACIATUS* SAY AND *CULEX PEUS* (DYAR) IN THE SOUTHEAST MOSQUITO ABATEMENT DISTRICT

Frank W. Pelsue[1], Gardner C. McFarland[1] and Patricia A. Gillies[2]

The development of resistances in many species of mosquitoes to "Public Health Protection Chemicals" (abbreviated PHP chemicals) has become a growing problem throughout the State of California, and the Southeast Mosquito Abatement District (SEMAD) has been no exception.

Resistance to organochlorine compounds was observed in the SEMAD during the late 1950's. At that time, the District was using DDT and toxaphene in its larviciding program. When the organochlorine compounds began failing in 1958, the District integrated the organophosphate chemical, malathion, into its larviciding program. This material lasted approximately three years as failures were observed in the early 1960's. Fortunately, this was the "golden age" of pesticide chemical development; consequently, new mosquito larvicides were continually being developed and when one chemical started to fail at the dosage rates for controlling mosquitoes a new material was substituted.

There were many materials to choose from when malathion failed, but most of these were not suitable for an urban mosquito control program due to their high mammalian toxicity.

The material of choice to replace malathion was fenthion. This material, although more toxic than malathion to warm-blooded animals, was easier on fish and could be used at much lower dosage rates than malathion.

As it became apparent that mosquitoes had the ability to become rapidly resistant to many of the PHP chemical larvicides, the SEMAD initiated its own resistance surveillance program in cooperation with the Bureau of Vector Control of the California State Department of Public Health. This program was started in 1963 after malathion was observed to be no longer effective in controlling mosquito larvae at economical dosage rates.

Fenthion was incorporated into the SEMAD's integrated control program in 1962 showing great promise of controlling all the major mosquito species at low dosage levels. Continuous monitoring of the susceptibility levels of our problem species *Culex pipiens quinquefasciatus* Say and *Culex peus* (Dyar) indicated a slow increase in tolerance levels in certain populations throughout the District. In 1967, we experienced our first control failure in *Culex peus* to fenthion. From this time on fenthion resistance became rather general throughout the District in *C. peus*. Although *C. peus* is not known to be a persistent biter of man, its

[1]Southeast Mosquito Abatement District, 9510 South Garfield Avenue, South Gate, California 90280.

[2]California State Department of Public Health, Bureau of Vector Control and Solid Waste Management, 5545 East Shields Avenue, Fresno, California 93727.

mere presence in a highly urbanized area such as Los Angeles County constitutes a problem to the general public. Consequently, PHP chemical resistance in the species is a real problem. The fact that this particular species of mosquito having rather high resistance levels to fenthion has caused the SEMAD to gear its choice of PHP chemical to control this species even though other more important species are still susceptible to the materials.

Culex p. quinquefasciatus and *C. tarsalis* also have shown resistance to fenthion since 1967. However, the resistance levels are not as high as those displayed by *C. peus.*

In 1969, fenthion was replaced by ABATE® in most areas of the District for mosquito larval control, while in some of the fringe areas fenthion is still effective, probably due to mixing of gene pools with mosquitoes that migrate in from uncontrolled areas, thus continually injecting susceptible genes into these populations. Ultimately, fenthion will be totally replaced by ABATE, Dursban®, Flit® MLO, and other larvicide oils. At the present time, Flit MLO is being integrated into the District's control program in most areas. The purpose of this is to stem the tide of resistance to organophosphate compounds and also to utilize the greater pupicidal qualities of the oil.

Fortunately, the resistance problems in the SEMAD are still low level compared to those encountered by certain districts in the San Joaquin Valley. The data reported in this paper will clearly indicate a lack of cross-tolerance or multiple resistance present in our resistant strains as compared with other strains in the state. This paper will be primarily concerned with the development of organophosphorous PHP chemical resistance in *Culex peus* and *Culex p. quinquefasciatus* as indicated by the title, since the bulk of our data was compiled after we began using organophosphorous compounds. We also have observed resistance to organophosphorous compounds in *Culex tarsalis.* However, we will report this resistance problem in a later paper.

MATERIALS AND METHODS.—The Southeast Mosquito Abatement District uses the laboratory procedures described by Gillies and Womeldorf (1968) of the Bureau of Vector Control, State Department of Public Health, in its resistance surveillance program. However, we deviate slightly from the State's procedure on some accounts; and these will be described as follows.

Fresh stock insecticide solutions are supplied to the District by the State Health Department. Serial dilutions are carried out to obtain the desired insecticide concentrations. Egg rafts are collected in the field and returned to the laboratory where the larvae are reared on a diet of Gaines meal, until they reach the fourth instar. The larvae are then transferred from the rearing pans into 4 oz papercups, containing 100 ml fresh tap water placing 20 larvae per cup. The larvae are then treated in duplicate with graded concentrations of the test insecticide. Mortality is recorded 24 hours after treatment. Controls are treated with 1 ml of acetone, but are only run periodically along with the regular test run. Each species from a given locality is tested separately and replicated once or twice depending on the availability of material and time.

The results of each test are plotted on log-probit graph paper and the lines fitted by eye. From this, the LC_{50} and LC_{90}'s are determined and expressed in parts per million. This information is sent to the Bureau of Vector Control and Solid Waste Management at the end of the season where the material is subjected to computer analysis and compared with tests run by State personnel from specimens collected in our District for correlative purposes.

The organophosphorous compounds we have been testing over the last ten years are as follows: malathion, fenthion, ABATE, Dursban, and parathion. Parathion is not used in the District's mosquito control program, but is used for comparative purposes to determine if cross-resistance or multiple resistance is evident.

RESULTS AND DISCUSSION.—Results of the various tests in our resistance surveillance program against *Culex peus* are presented in Table 1. We began our routine surveillance program in 1963 and at that time *C. peus* had approximately a five-fold resistance to malathion with an LC_{50} value of 0.11 as compared with a susceptible strain having an LC_{50} value of 0.026. The susceptible strain is maintained in the BVC laboratory in Fresno, and data presented in this paper is compared to data compiled from testing on their strain. Malathion resistance in *C. peus* peaked out in 1966 with a LC_{50} value of 0.23 ppm indicating an approximate 8-fold resistance to malathion. This evidence would tend to confirm definite biochemical resistance in our particular strain. Malathion resistance levels continued to increase from 1963, even though we integrated fenthion into our control program in 1962 relaxing malathion selection pressure. However, it appears from the slopes presented in Figure 1 that our population was rather homogenous for resistance. However, an interesting fact has come to light, we can show a slight regression in resistance levels in tests run in 1970.

Table 1.—Yearly average LC_{50} and LC_{90} value in ppm for *Culex peus* for the various public health protection chemicals.

1965

Material	1965 LC_{50}	1965 LC_{90}	1966 LC_{50}	1966 LC_{90}	1967 LC_{50}	1967 LC_{90}	1968 LC_{50}	1968 LC_{90}	1969 LC_{50}	1969 LC_{90}	1970 LC_{50}	1970 LC_{90}	1971 LC_{50}	1971 LC_{90}
Malathion	0.10	0.19	0.19	0.45	0.23	0.40			0.092	0.28	0.086	0.15	0.065	0.11
Fenthion	0.0014	0.018	0.016	0.047	0.015	0.032	0.045	0.20	0.058	0.18	0.055	0.10	0.037	0.086
ABATE®	0.00087	0.0012	0.0019	0.0035	0.00082	0.0014	0.0013	0.0021	0.0025	0.0044	0.0035	0.0040	0.0016	0.0040
Dursban®			0.0014	0.0039					0.0010	0.0018	0.0006	0.001		
Parathion	0.0023	0.0041	0.0035	0.0053							0.0028	0.0043		

Table 2.–Yearly average LC_{50} and LC_{90} (ppm) for *Culex quinquefasciatus* for the various public Health Protection Chemicals.

Material	1965 LC_{50}	1965 LC_{90}	1966 LC_{50}	1966 LC_{90}	1967 LC_{50}	1967 LC_{90}	1968 LC_{50}	1968 LC_{90}	1969 LC_{50}	1969 LC_{90}	1970 LC_{50}	1970 LC_{90}	1971 LC_{50}	1971 LC_{90}
Malathion	0.067	0.13	0.089	0.16	0.083	0.15								
Fenthion	0.0056	0.015	0.0044	0.0075	0.0053	0.013	0.0062	0.0089	0.0052	0.010	0.0061	0.012	0.0077	0.014
ABATE®			0.0018	0.0026	0.00039	0.00064			0.0018	0.0022	0.0016	0.0035	0.0016	0.001
Dursban®			0.00090	0.0015	0.00060	0.0010								

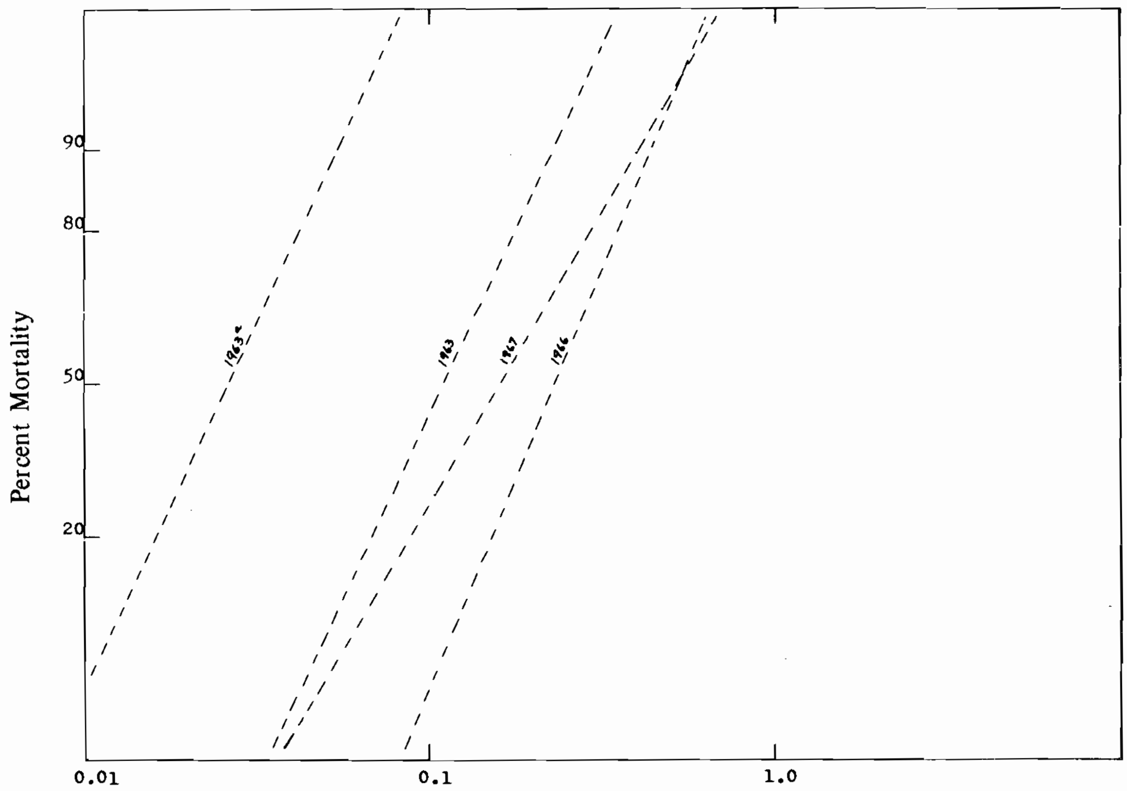
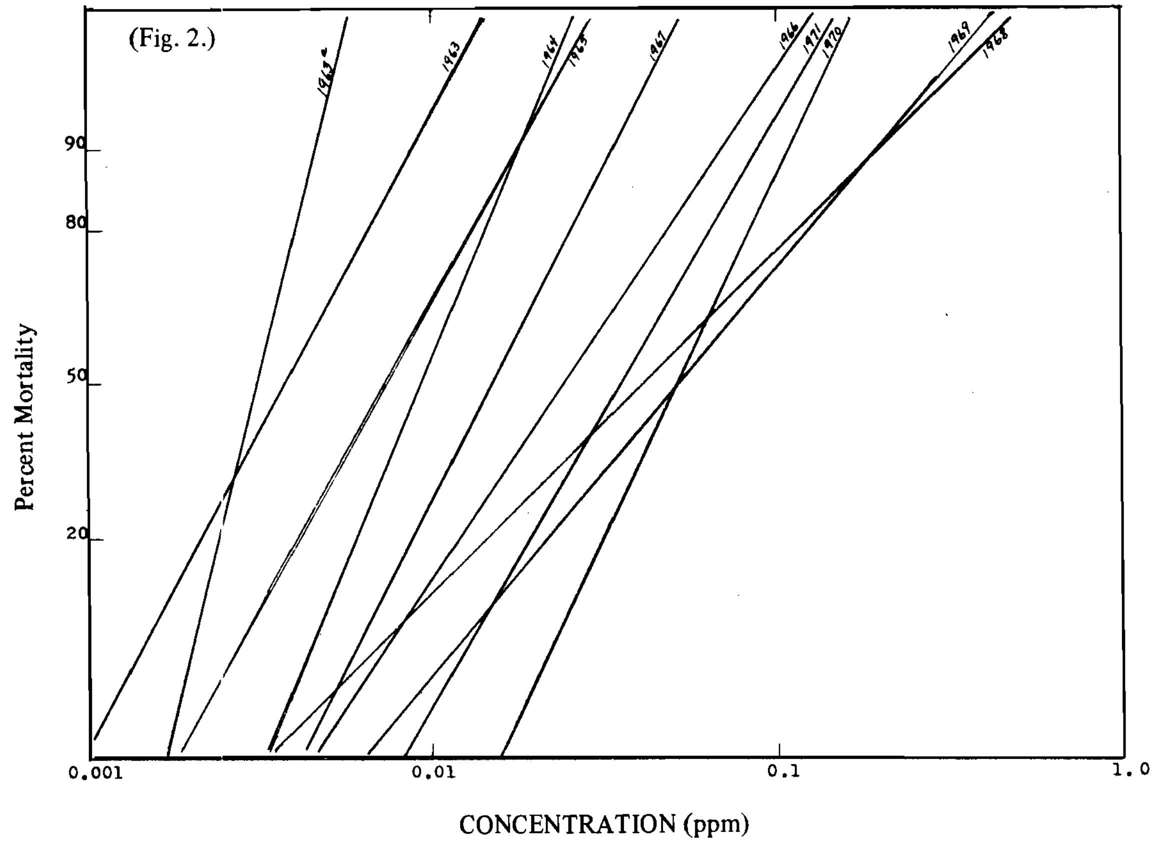


Fig. 1.–Shows LD-p lines for susceptible strain as compared with resistant strain of *Culex peus* for malathion. Based on computer analyzed data.

These results showed an LC_{50} level of 0.086 indicating a four-fold decrease in resistance to malathion. However, this decrease in resistance is not very significant and is to be expected after prolonged relaxation of malathion selection pressure.

Malathion resistance in *Culex p. quinquefasciatus* is quite different than what we have found in *C. peus.* Resistance rates in this species are only approximately three-fold ovei a comparable susceptible strain, as indicated in Table 2. Even though *C. p. quinquefasciatus* and *C. peus* occur in similar larval habitats and were essentially subjected to the same amount of malathion selection pressure, there appears to be considerable difference in their ability to detoxify or metabolize malathion. Perhaps in the case of *C. p. quinquefasciatus*, the magnitude of tolerance exhibited is only a "fitness" tolerance to insecticide and not true biochemical resistance. The evidence indicates that over the years malathion resistance in this species has remained rather constant in the LC_{50} range of 0.08 ppm on the average as compared with a susceptible strain with a LC_{50} of 0.026 ppm. The average LC_{50} value in *C. p. quinquefasciatus* is approaching the 0.1 ppm level indicating that we would expect to exper-



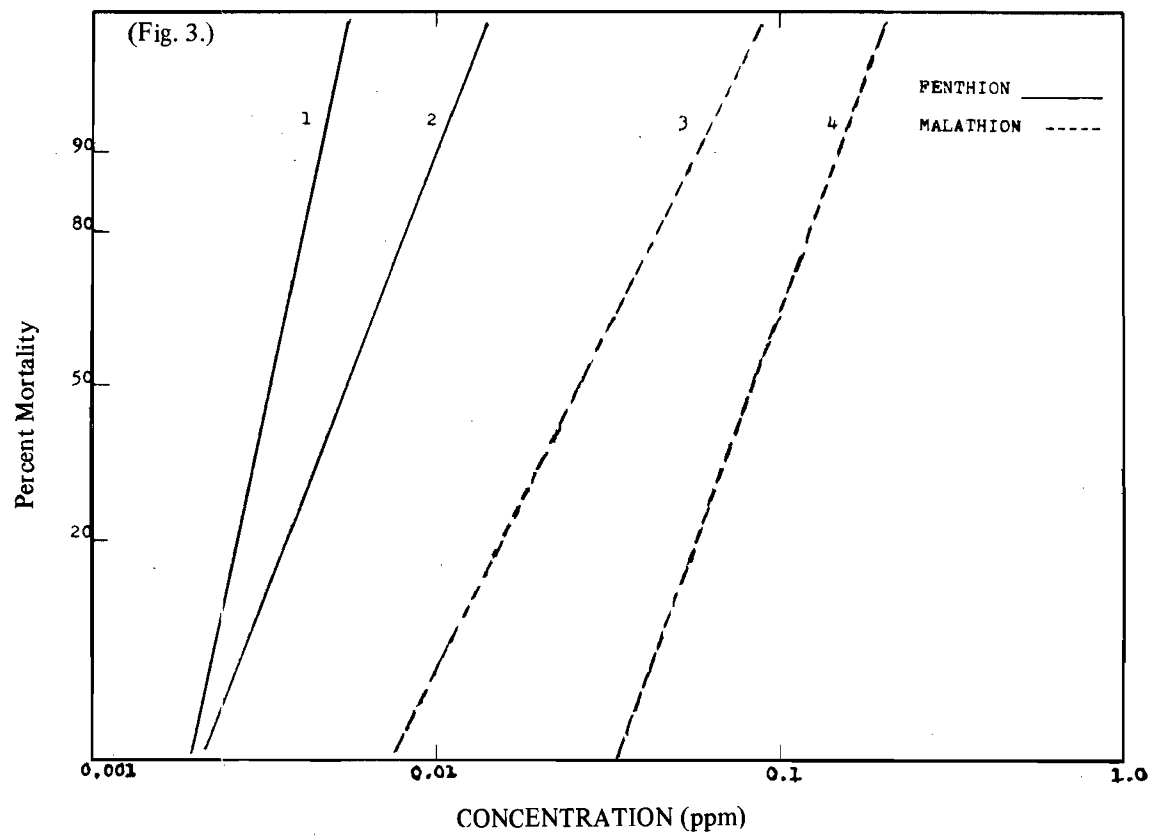


Fig. 2.–Comparison of LD-p lines for *Culex peus* of fenthion susceptible and resistant strains showing the progression of resistance. Based on computer analyzed data.

Fig. 3.–LD-p lines 1 and 2 represent a comparison of a susceptible strain of *Culex quinquefasciatus* with the SEMAD strain (yearly average from 1964-date). Lines 3 and 4 represent a comparison of a susceptible and the SEMAD strain of *C. quinquefasciatus* for malathion. Data based on computer analyzed data.

ience control failure with malathion against this species. Relaxation of malathion selection pressure has not tended to significantly change the level of resistance over the last several years of *C. p. quinquefasciatus* to malathion. The use of fenthion on both *C. peus* and *C. p. quinquefaciatus* has not increased or imparted greater resistance to malathion, leading one to conclude that malathion resistance has not produced a cross-tolerance to fenthion in either species.

Fenthion resistance in *C. peus* was first demonstrated in 1966 in the SEMAD. The LC_{50} level at that time was 0.024 ppm as compared to the susceptible strain with an LC_{50} level of 0.0031 ppm, indicating an approximate eight-fold increase. In 1967, we experienced control failures at dosage rates of 0.1 pound of actual ingredient per acre. Fenthion resistance reached a peak in 1968 for this species with an LC_{50} level average of 0.05 ppm, giving us an approximate 14-fold resistance ratio increase over the susceptible strain. In 1969 we relaxed fenthion selection pressure by switching to ABATE for most areas of the District. Continued testing in 1970 and 1971 as presented in Table 1 has shown a slight regression in the resistance level, to an LC_{50} value of 0.037 ppm. This is not considered significant at this time but is a point of interest. In 1971, in most areas of the District Flit MLO was used on a wide scale. This may contribute to the reduction in larval resistance exhibited by *C. peus* to fenthion. Further testing should confirm this hypothesis in time.

In testing fenthion against populations of *Culex p. quinquefasciatus*, we found a pattern of fenthion selection similar to what occurred with malathion selection. Resistance ratios to fenthion in this species indicated only an approximate two-fold increase over a susceptible strain of the same species. This evidence correlates with the evidence regarding resistance to malathion in this species. As stated before, both *C. p. quinquefasciatus* and *C. peus* are subjected to the same selection pressure from any of the PHP chemicals used in the District. This clearly indicates a biochemical difference between the two species in terms of insecticide metabolism.

Figure 3 compares the LD-p lines for fenthion of the susceptible strain of *C. p. quinquefasciatus* with the SEMAD tolerant strain averages, indicating only a slight shift in the line with considerable overlap. The data clearly shows a lack of significant change between the susceptible and tolerant strains, thus supporting the hypothesis that no biochemical resistance is present in this strain at the present time.

Both *C. peus* and *C. p. quinquefasciatus* remain susceptible to ABATE and Dursban as shown in Tables 1 and 2. With the use of Flit MLO and other larvicide oils in our control program, we should be able to slow down the rapid buildup of resistance to the organophosphate compounds. Hopefully, mosquitoes will not be able to develop resistance to larvicide oils.

Acknowledgement

The authors would like to thank Dr. Kathleen E. White and Don Womeldorf and other members of the staff of the Bureau of Vector Control of the California State Department of Public Health for providing the tabulated statistical data and the stock solutions of chemicals used in the resistance testing.

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RESISTANCE FORCES A NEW BLUEPRINT FOR CALIFORNIA MOSQUITO CONTROL

Stephen M. Silveira[1], Melvin L. Oldham[2] and Ronald L. Wolfe[3]

Organophosphorus insecticide resistance in *Culex tarsalis* and *Aedes nigromaculis* now exists in several areas in California. Severe cross tolerance has extended to all organophosphorus materials in a number of local mosquito control agencies. It is doubtful that the answer to insecticide resistance will be provided by a new so-called conventional insecticide in the near future, and so it is becoming quite evident that California can no longer rely on pesticides as the primary tool for mosquito control.

SURVEY.—How are mosquito abatement districts in California planning to control mosquitoes in the absence of highly effective pesticides? In an attempt to provide an answer, we circulated a questionnaire. We asked questions like —— How will insecticide resistance affect your budget and financing? What personnel changes will be required? What change in equipment will be needed? How will it affect your insecticide usage? What part will public relations play? Will legal activity be increased?

[1]Turlock Mosquito Abatement District, P. O. Box 1629, Turlock, California 95380.

[2]Tehama County Mosquito Abatement District, 429 Ash Street, Red Bluff, California 96080

[3]Goleta Valley Mosquito Abatement District, P. O. Drawer 460, Goleta, California 93017.

We received 30 replies from approximately 58 agencies contacted. The general question was asked: "Is resistance causing your district to modify its policies and operational program?"

The answers reflect the area of the state most severely affected by resistance:

Region	Yes	No
Costal	0	4
Southern	1	8
Central Valley (Sacramento; N. & S. San Joaquin)	16	1

Several Southern California mosquito control agencies commented that midge resistance poses a greater problem than does mosquito resistance.

Answers to specific items in the questionnaire are summarized by the three areas in Table 1.

DISCUSSION—Finances.—Eight of the 30 agencies foresee an increase in costs due to resistance. Reasons given include anticipated greater expense for larvicidal oils and their application, the need for more manpower, grants for research, cost sharing with farmers for mosquito prevention projects.

Another eight agencies indicated that funds would be reallocated. The principal reasons were shifting emphasis from chemical control to biological control and mosquito prevention.

Public Information.—More agencies plan to increase their efforts in this program aspect than in any other. Of the 30 respondents, 21 will up activity in this area. It is increasingly apparent that the message must be brought to the people who are directly affected by mosquitoes and who must pay for their control.

Personnel.—Nearly half of the responding agencies (14 of 30) will increase their force or will reassign duties. The areas of activity which need bolstering include those of technical information, including intensified inspecting, record keeping, and evaluation. Water management education was cited as an important new role, requiring technically trained personnel. Some agencies anticipate that more labor will be required with oil larvicides. Upgrading competency was seen as a need, which will be accomplished either through training existing staff or being more selective when choosing new employees.

Equipment.—Few agencies will add to their existing equipment, but more plan to reallocate what they have. Additions or reallocation appears to be planned to provide the necessary support to increased or reassigned staff.

Research.—Two directions were emphasized. In-district research will be directed toward developing and evaluating larvicides and adulticides and biological control agents. Several districts plan to continue to provide financial support to the University of California research program and to maintain close working relationships with all research agencies.

Legal Aspects.—Eleven of the 30 agencies said that they plan to give increased attention to the possibilities of legal action. Although some will begin immediately to force compliance, the majority will review district policies with an eye toward abatement procedures. The consensus seems to be to go cautiously if at all into a legal-action program, using

Table 1.—Anticipated program modifications, by agencies in three California areas, as a result of mosquito insecticide resistance development.

	Change											
	Increase area			Decrease area			Reallocation area			None area		
Program Aspect	Coastal	Southern	Central Valley	Coastal	Southern	Central Valley	Coastal	Southern	Central Valley	Coastal	Southern	Central Valley
Finances	1	2	5	0	1	0	0	1	7	2	5	1
Public Information	1	5	15	0	0	0	0	0	0	3	4	0
Personnel	0	2	8	0	0	0	0	1	3	4	6	6
Equipment	0	1	2	0	0	0	0	1	5	4	7	6
Research	2	5	7	0	0	0	0	0	0	2	3	7
Legal	1	0	10	0	0	0	0	0	0	2	9	5
Larvicides	1	1	0	2	0	11	0	1	0	1	4	1
Adulticides	0	0	9	2	0	4	0	0	0	2	4	0
Oils	1	4	11	0	0	1	0	0	0	2	4	1
Biocontrol	3	5	11	0	0	0	0	0	1	1	3	4
Mosquito Prevention	1	4	12	0	0	0	0	0	0	3	5	2

this means as a last resort if all else fails.

Chemical Control.–Resistance is bringing about two major changes in the chemical control programs of the responding agencies. Half see an increase in the use of oil larvicides, generally at the expense of the organophosphorus compounds. It is interesting that this trend is apparent in the urban areas as well as the rural parts of the state. The change will probably be much less disruptive to urban than rural programs.

The second change is an increase in adulticides at the expense of larvicides. These materials will be used selectively in areas of need, and will not be used in the extensive areas that larvicides have.

A number of districts anticipate a decrease in all chemical use due to resistance, with emphasis being shifted to other control methods.

Biological Control.–At present, practical biological control is limited to the use of larvivorous fish, principally *Gambusia.* Nineteen of the 30 agencies anticipate increasing dependence upon mosquito fish. There are needs for improved handling, rearing, and distributing techniques, and at least two districts are conducting research along this line.

Mosquito Prevention.–Seventeen of the 30 agencies plan to increase efforts in this program area. The impact of the extra emphasis is broad. Several of the agencies commented that all staff would be involved, that public information would be tied into the program, that it would be related to legal aspects, and that it is closely allied with water conservation and quality protection. It is seen that water management offers the greatest hope for most effectively and rapidly reducing mosquito production, with the classic approaches of land leveling, filling, and draining being long-term approaches.

In summary, it is apparent that resistance will cause greater immediate changes to agencies in the rural areas of the state. The effects of resistance will be far-reaching and result in permanent modification of the approach to mosquito control. The public will be brought closer to the whole problem and will be increasingly involved. Reliance on chemicals will be reduced, and integration of biological control agents will be increased. Mosquito provention will emphasize water management as an immediate aim. And, finally, the legal club will be held in reserve as long as possible.

MOSQUITO CONTROL SHIFTS TO PREVENTION

Richard H. DeWitt
Kern Mosquito Abatement District
P. O. Box 1271, Bakersfield, California 93302

The subject of this panel "Mosquito Control Shifts to Prevention" is, I think, quite appropriate. Since our last Annual Conference there seems to be a quieter and more serious attitude amongst us, somewhat different from the frustration of a year ago. I am, of course, referring to the resistance problem.

I think it would be safe to say that every district in the state that has experienced a serious resistance problem has begun to shift the emphasis from insecticide control to other methods . . . Preventative Methods in one form or another, and why?, because we have finally had to.

Recently, I have taken the time to go back and review some of the CMCA papers from past Proceedings and it is interesting to note how much has been said on the subject of Preventative Control and How Little has actually been done about it.

Some of us, including myself, have been beating the drum on the benefits of Source Reduction for the past twenty years or so and yet there are still many districts that do not really use this important tool in a working program. To know the benefits and long lasting results of source reduction is to experience it, to make it a tool of your program.

I have used source reduction as an example of one of the important preventative control measures, actually there are others equally important. This panel will be discussing some of these today. I like to think of all of the preventative measures as tools, tools to be used as an important supplement to the overall mosquito control program.

It is true that there will always be a need for larviciding by one means or another. The day might well arrive when we will have another miracle insecticide. This may not be soon and it could be very expensive. In the meantime, if we have used our preventative tools wisely and well, perhaps our problems may become small enough and few enough that we can afford the use of an effective and expensive insecticide.

I would like to sum it all up by using the much used old adage –– "An ounce of prevention is worth a pound of cure", but after all isn't this really what we are talking about.

THE ABATEMENT PROCEDURE

J. Warren Cook

Madera County Mosquito Abatement District

1928 Howard Road, Madera, California 93637

The primary reasons for the needed change in the Madera County Mosquito Abatement District policy were the resistance problem that was rapidly developing, the ecology movement calling for a slow-down in use of all pesticides, and the increased awareness on the part of the Board of Trustees that although the costs of insecticides and their application were rising, an adequate level of mosquito suppression was not being obtained.

The decision of the Board was to shift more emphasis toward source reduction and source elimination. Since Madera does not own or operate large equipment, it would be the responsibility of the property owner to make the necessary corrections.

As a means of implementing this decision, the largest and most chronic offenders were notified through newspapers, radio, and verbal or written notices that failure to cooperate in eliminating mosquito sources on their property could result in legal action being taken against them.

Cooperation on the part of governmental agencies was sought initially. It was felt that private owners would be more responsive if public agencies were already in compliance.

Statements of costs were mailed to all governmental agencies that had failed to cooperate even after written notice; and were producing mosquitoes through negligence.

These were the only bills ever sent, and never has the District tried to recover expended funds from any private individual.

Lack of response on the part of the three worst offenders to either heed the plea for cooperation or the billing, prompted the Board to hold special hearings with these offenders. Of these three, the County of Madera responded with both monies and increased cooperation, the irrigation districts with cooperation, and the City of Madera failed to cooperate in correcting its two major sources.

ABATEMENT PROCEDURE.—Since it was apparent the City did not intend to correct these sources, legal abatement procedures were initiated against it.

In a two-pronged attack it was served with orders from the Madera County-City Health Officer and the District Board to abate the breeding of mosquitoes. It was given a hearing date four days from the date of service of the orders. The order specified that plans be submitted within ten days and that corrections be commenced within twenty days after service of the order. The City did comply with the order, and in so doing eliminated the major mosquito source in our District. This culminated years of effort on the part of the District to achieve this end.

Subsequently a suit for a little over two thousand dollars, covering expenditures by the District for July, August and September 1970, was filed against the City. This suit did not follow all of the procedures set forth in the Health and Safety Code.

The suit was filed under a writ of mandate. One reason for this was to gain an early court date. The ruling of the Judge was: "An unliquidated claim cannot be the basis for a writ of mandate against any governmental agency".

The action was ruled improper for three reasons, primarily because of the writ of mandate. The Judge also ruled the claim was not "verified", as per Section 2289, and that the wording in Section 2289 implying that a governmental agency "shall repay" any District cost is not sufficient to short cut the procedures set forth in the Health and Safety Code, Sections 2274-2289. He also emphasized governmental agencies must be given the same rights due private citizens.

With private, as well as government agencies, a three part notification system has been developed by the Madera County MAD consisting of a warning, a citation, and finally legal abatement action. These are served on consistent violators.

The warning informs the violator of the problem he is causing, and is accompanied by educational literature, information regarding where he may seek financial and engineering help, and a map of his property showing him exactly where the problem area is.

The citation is issued to the offender if there is no effort made to correct the source and it continues to be a problem to the District. It notifies him to appear at a designated time at the District office to discuss the problem and to show cause, if any, why an abatement notice should not be filed against him.

Up to here we are still seeking cooperation in solving the problem. At this point if cooperation is not immediately forthcoming, and at the discretion of the District Board, a legal abatement order will be served.

In 1971 approximately one hundred twenty-two warnings were issued and discussed with the individuals concerned. Only one legal abatement notice has been served on an individual. He was ordered to submit plans for abatement of the nuisance within a certain period for approval by the District Board. Although the project has not been thoroughly completed, it appears he intends to comply.

The District seriously feels that only a limited number of abatement notices will need to be served to convince the public of the seriousness of the situation and the need for them to cooperate in the abatement of mosquitoes on their own property.

It is not the intention of the Board to seek reimbursement of all costs or to continually harass individuals. Rather, it is to convince them it is for their own benefit that the District has made the changes it has. Changes in cultural practices that have produced mosquitoes in the past should result in better crops, higher milk and meat production, and a better recreational environment, as well as other aesthetic and practical benefits.

In my own opinion the warnings, in conjunction with increased public education, have already resulted in elimination or modification of a number of existing sources as well as many in the planning stage.

A joint meeting was held on January 14, 1972 between the northern and southern San Joaquin regions. A committee of five was appointed to work on a step by step legal procedure, as well as a uniform manner of charging for services. The committee consists of two representatives from each region and a member of the staff from the State Bureau of Vector Control, who will serve in an advisory capacity.

It is hoped this committee will be able to work out and recommend a simplified, acceptable procedure that the district boards could, at their option, adopt as policy.

It appears that it is not as essential that each district necessarily use the same wording in the construction of its forms, but rather that the procedures themselves be uniform.

Another extremely important factor is the manner in which charges are assessed. All districts that do charge should be charging for the same services even though the cost for those services might vary from district to district. For example, as long as one district is charging for insecticide but not the airplane, and a neighboring district is charging for both, we do not have uniformity; and this could cause problems.

In December I mailed out sixty-three questionnaires asking if any district had utilized the provisions of the Health and Safety Code either for the collection of monies or for the abatement of a mosquito source. I received a response from thirty-seven districts, and of these, eleven have used the Code, seven to collect monies. There were three that plan on using it this year and two have threatened its use in the past. The majority felt a definite need for the districts to develop a uniform procedure. The information and forms sent to me by other districts will be turned over to the committee endeavoring to develop a procedure, and I am sure will prove to be most helpful.

While there are those of us who feel we must have one procedure for all districts to follow, it is not intended that all districts must necessarily serve abatement notices and/or charge for their services. Naturally, it is up to each individual district to decide if it wishes to take this approach; but if it does, there should be a complete updated procedure available for it tc follow. Lengthy procedures have been proposed in the past. It is hoped that these can be streamlined, where possible, to better meet the needs of current district programs.

IRRIGATION MANAGEMENT AND MOSQUITO PRODUCTION

Lloyd E. Myers

U. S. Water Conservation Laboratory

Agricultural Research Service, United States Department of Agriculture, Phoenix, Arizona

I was initially very pleased to accept the invitation to appear on this panel. Then, about two weeks ago, it suddenly dawned on me that it had been 18 long years since I left California and that I really didn't know what has been going on in California mosquito control since that time. Listening to the conversations here, however, it sounds as though I have come back to the same situation I left. In 1954 the chlorinated hydrocarbons were failing to kill mosquitoes and everyone was talking about increasing source reduction programs. Today, the organic phosphates are failing and everyone is talking about increasing source reduction programs. The only thing that has changed is the name of the insecticides. So perhaps my information is not so far out of date. In view of this, there are two problems I would like to once again bring to your attention.

The first problem relates to the adequacy of the information we need to reduce mosquito production in irrigated pastures. I would like to quote from a paper on "Irrigation Efficiency and Mosquito Production" printed in the June, 1956 issue of Mosquito News.

"Human nature being what it is, the correction of some irrigation-caused mosquito problems will have to be obtained through the enforcement of laws pertaining to public health, public safety, and public nuisances. Law enforcement is not ordinarily a popular way of doing business and is usually quite difficult. Some irrigation-caused mosquito problems can be corrected through the desire of some agencies, such as irrigation districts or county road departments, for good public relations. This approach does not always work, as we all know. The easiest and best approach, in the long run, will be to prove that efficient irrigation and water use practices not only reduce mosquito production but save water and increase crop production. We will then be in the excellent position of being able to show that the practices which should be adopted for mosquito control are the same practices which should be adopted for improved water use and crop production.

"We should remember that when we work to correct irrigation practices which cause mosquito problems we are dealing with the bread and butter operations of the irrigation farmer. Our corrective programs must be based on facts, not deductive reasoning. The research we do to collect the needed facts must be based on sound scientific principles and must consider all aspects of the problems we are investigating."

Now the question is, where do we stand in regard to having these facts?

Nearly every publication on irrigation system design and management states that proper field leveling and efficient irrigation management will save water and increase crop production. Numerous publications on irrigation mosquito production, including some I have written, say that proper field preparation and efficient irrigation management will: (1) save water, (2) reduce mosquito production, and (3) increase crop production. Since so many experts say that these three things are so, they must be so. Or are they? In particular, are they true for irrigated pasture?

(1) There have been hundreds of studies showing that improving irrigation efficiency saves water. We are on solid ground when we make that statement because we have data to prove it.

(2) We have conducted several studies to show that efficient irrigation systems and efficient water management can essentially eliminate mosquito production within fields of all irrigated crops except rice. We have a reasonable amount of data to back-up that statement, and we are safe in saying it.

(3) But when we say that efficient irrigation increases crop production we are saying something we may not always be able to prove. We can find data to show that, under some conditions, excessive irrigation of some crops can reduce production. I do not believe we have adequate data to prove that this is true for irrigated pastures. Except for some work near Chinook, Montana, I do not believe we have gotten yield data in conjunction with studies of irrigation efficiency and mosquito production. Unfortunately, the Montana study does not directly apply to California conditions. Perhaps the necessary data do exist, but I have not as yet been able to find them. If the data do not exist, we need to obtain them. Otherwise we may be in the embarrassing position of being unable to prove something we have been saying for years.

I said in 1956 that this work would require the combined efforts of entomologists, agronomists, soil scientists, irrigation engineers, and other specialists. And I said that, since no one agency has all these specialists, we should work to develop cooperative projects involving both public health and agricultural research agencies. At that time we had made a good start. The University of California had issued a bulletin entitled "Mosquito Control on the Farm". Agricultural Research Service engineers were working with the California Bureau of Vector Control and the California Mosquito Control Association on pasture irrigation and mosquito problems. The U. S. Public Health Service and the Agricultural Research Service had initiated the Montana studies. Some of us were working on a statement of "Principles and Practices for Prevention of Mosquito Sources Associated with Irrigation" which was adopted as an official recommendation of the American Society of Agricultural Engineers in 1958. In 1958 the Water Resources Center of the University of California issued a report on "Suggestions for Research in Water Resources" which included two research proposals related to mosquito problems. But there the trail ends, at least in the publications in my files. Apparently we have lost contact in some areas that seem to me to be important, and that is the second problem I want to mention here. I will not belabor the point, for most of us are aware of it. There is, however, one piece of evidence that should be brought to your attention.

A document was published in October 1966 that was entitled "A National Program of Research for Agriculture". This recommended program, which is now a required reference for agricultural research planning, was prepared by the Association of State Universities and Land Grant Colleges and the U. S. Department of Agriculture. More than 100 experts, intended to represent all aspects of agriculture, participated in preparing the report. The report is 272 pages long, lists multitudes of agricultural problems needing research, and recommends the relative effort needed on these problems. The writers of the report were concerned with environmental problems created by, or detrimental to, agriculture. The listed problems related to such things as animal wastes, fertilizers, pesticides, and dust. Research on mosqutioes was mentioned in terms of biology, insecticides, repellents, and biological controls. But nowhere is there mention of environmental or public health problems associated with irrigation. This means to me that the people preparing this report were not familiar with the magnitude or importance of irrigation-caused mosquito problems, which are certainly not confined to California. The people who are planning and directing agricultural research programs have not yet gotten the message, or, if they ever got it they have now forgotton it.

I will close by repeating what I said in 1956. We need to develop information to prove that proper irrigation increases crop production as well as saving water and reducing mosquito production. This will require cooperative effort by both public health and agricultural research agencies. We must explore and exploit all possible means of developing that cooperation. Perhaps you have done this, or are doing it, or have plans to do it. If so, I extend my congratulations and best wishes. If you have not, then all I can say is –– time's a'wasting. Let's pull up the anchor and start paddling. And let's all paddle in the same direction.

ECONOMIC CONSIDERATIONS IN PASTURE REHABILITATION

Reuben Junkert[1] and Armand P. Quintana[2]
California State Department of Public Health
Bureau of Vector Control and Solid Waste Management

Economics of pasture rehabilitation is not a pure analytical problem because we deal with people who make land use and management decisions that reflect their personal desires, needs and attitudes. In many cases rehabilitated pastures still will need an integrated program of chemicals and biological controls to minimize the production of mosquitoes. Proper water management is basic and has been described by Sutherland et al. (1967), as to (1) eliminate the water by draining or filling, (2) keep the water circulating, and (3) maintain the water in a manner unsuitable for mosquitoes. Another basic requirement is "Don't apply more water than necessary". Other researchers have studied the problem and arrived at similar conclusions.

Source reduction includes good water management and often requires physical changes in the land. The latter alternative is, in most cases, now almost entirley dependent on the landowner's willingness to bear the cost of making physical changes in his land. When advocating changes, source reduction personnel should be ready to advise on sources of economic help that may be available to the landowner who is willing, or required, to make these necessary and generally expensive improvements. Alternate designs and related costs must be investigated so that the owner has some flexibility, allowing him a choice among several positive methods rather than forcing a "yes" or "no" answer. Major considerations such as direct aid, depreciation, crop yields, and income tax benefits are all part of the economic picture.

DIRECT AID.–Federal assistance programs designed to aid farmers in reclamation projects are quite often unknown to the land-owner or he is unwilling to participate because proper engineering is required.

Within the federal government, the Agricultural Stabilization and Conservation Service (ASCS), U. S. Department of Agriculture, administers the Rural Environmental Assistance Program (REAP), which is designed to aid farmers in, among other things, conservation of farm resources. Through this program the federal government shares in the cost of conservation practices which reduce pollution, protect the soil, provide for more efficient use of land and water, benefit wildlife, retain open space, and beautify the country's rural areas. In this program each county selects applicable practices from a statewide list and cost-sharing is authorized on the basis of a landowner's need and benefits created. To determine eligibility a landowner must contact the local ASCS office and file a formal application for cost-sharing before doing any work on the project.

Mosquito control has not been included in the program as a conservation practice and is, therefore, not eligible for cost-sharing. Efforts are being made to define a practice aimed specifically at mosquito control measures. If approved and successful, this could become a very important means of mosquito prevention and land improvement.

Meanwhile, several of the current cost-sharing practices intended for control of pollution also have the effect of reducing or eliminating mosquito breeding sources. This benefit is inherent in the following REAP practices which can be encouraged when a mosquito problem exists:

1. Construction of terrace systems, ditches, or dikes.
2. Special stream bank, or shore, protection projects.
3. Reorganizing irrigation systems.
4. Animal waste storage and diversion facilities.
5. Tailwater recovery systems.

Except for certain pooling agreements, cost-sharing for these practices varies from 50% to common upper limits of $500 or $2,500 per person, depending on the kind of project and local limits. Regardless of the program or monetary amount available, cost-sharing by the federal government can be looked upon as a possible incentive for the landowner to make improvements which will directly or indirectly eliminate or reduce mosquito production on his land.

Cost-sharing through the REAP program produces taxable income; therefore, the biggest benefit is in cash flow. This taxable income will be discussed in later paragraphs.

IMPROVED YIELD.–The usual approach is to determine whether source reduction costs will be self-liquidating by increased yields. Unfortunately, the answer to this approach is not always simple. Many factors determine the feasibility of making a change, among them the original condition of the land, amount of land lost due to poor water management, amount of land that will be reclaimed or improved, use of the land, expected increase in production, and perhaps the biggest variable of all, water management practice. Water management can make or break almost any project.

INCOME TAX.–Expenditures for improvements to land or facilities fall into two categories: operational and capital. Operational expenditures are deductible items for both state and federal income tax purposes, but the cost of capital improvements can only be recovered by depreciation extended over the useful life of the asset.

Operational costs include such items as fertilizers, seed, land tax and certain expenditures for leveling, regrading, terracing, ditching. Under current Internal Revenue Service rules, releveling should be fully deductible provided that the cost is less than $5,000 or 25% of gross income, or can qualify as a "Soil and Water Conservation Practice". Practices that qualify as "Soil and Water Conservation Practices" have only the 25% limitation per year and excess amounts can be carried over to succeeding years. Interpretation of

[1]Mosquito Surveillance and Prevention, Office Building No. 9, 744 P Street, Sacramento, California 95814.

[2]Mosquito Surveillance and Prevention, 5545 East Shields Avenue, Fresno, California 93727.

the guidelines is necessary to determine whether an improvement is an operational cost or a "Soil and Water Conservation Practice".

It appears that source reduction, where we are definitely trying to encourage good water management, would automatically qualify as a "Soil and Water Conservation Practice". One exception is given in the Internal Revenue Tax Guide. Expenditures made to change the use of the land will not qualify. For example, if pasture land is purchased and prepared for use as a citrus grove, such expenditures will not qualify.

Capital improvements are those which have a useful life of more than one year and are subject to an allowance for depreciation. Examples are concrete pipe, drain tile, wells and concrete structures. Development of new land is generally a capital improvement. In our opinion, recovery of these capital costs by depreciation is no incentive to make improvements.

LAND TAX.–The County Assessor determines the policies to be followed in assessing improvements made on the land. He, in turn, is bound by policies set up by the County Board of Supervisors and state law.

County taxes on farms are based on the market value of the land and on improvements thereon. Leveling farm land, installation of irrigation pipelines, pumps, and other irrigation facilities are generally considered improvements that tend to increase the value of the farm and are, therefore, taxable. Regrading previously leveled land is generally considered to be a maintenance operation and will not necessarily result in higher land taxes. This possible increase in land tax is nearly always a favored argument or justification for not making improvements. It also becomes a sensitive spot for mosquito abatement and source reduction personnel when improvements are desired for abatement purposes.

ABATEMENT DISTRICT EQUIPMENT AND FARMER RESPONSIBILITY.–There exist pastures that cannot be economically rehabilitated. The argument that the landowner who relevels his land, installs a pipeline or a water recovery system also reaps great financial benefits from the improvements sometimes becomes weak.

This is the area where abatement district equipment and personnel can be used to good advantage. The owner may need to be educated and his operation might have to be improved, but it would be realistic for the district to spend some money to make physical changes to reduce mosquito production rather than continue to apply insecticides with no thought of getting to the heart of the problem. Both are a kind of subsidy, but source reduction would be a constructive move in the right direction. This has some fringe benefits. The chances are good that the work will be done correctly, and the total cost could be less because of the higher rates and general reluctance of many commercial firms to take on small jobs.

Another approach toward the solution of the uneconomical projects is making the farmer aware of his responsibility. The uneconomical project should not be a license for him to continue his method of operation, thereby creating a public nuisance and possible health hazard. The present trend of growing public interest in control of chemicals, noise, water and air pollution can also be extended to control of mosquitoes.

PASTURE REHABILITATION EXAMPLES.–The following two examples can be called economic extremes in pasture rehabilitation because the answer to each was clear cut, but between these two extremes are countless variations and each case must be evaluated before improvement decisions and recommendations are made.

These examples are case histories from the first six months of the Mosquito Surveillance and Prevention Unit source reduction efforts.

Example 1.– Approximately 39 acres were taken out of irrigated pasture, releveled and will be used for row crops, oats and corn. The original condition of the pasture was poor. Weeds and water grasses were abundant.

The following figures show the potential. All figures are approximate and have been rounded off.

Improvement costs:

Leveling and land planning	$ 57/acre
Concrete pipe and turnouts	116
Subtotal	$173
Estimated cost-sharing	– 13
Net Cost	$160/acre
Total Cost $6,240	

Income:

Value of oats crop	$ 75/acre/year
Value of corn crop	120
Subtotal	$195
Overhead	–100
Net gain above overhead	$ 95/acre/year
Present worth of pasture	– 50
Net gain above original return	$ 45/acre/year

Assuming $500 of the pipeline cost is paid by funds from outside agencies, the out-of-pocket cash would be about $160/acre or $6,240. At 8% interest the $45/acre gain will amortize the $160/acre improvement in less than five years.

For income tax purposes the land leveling and planing would be deductible expense and depreciation would be allowed on the pipeline and permanent structures. At the 19% federal tax bracket this would save about $515 in state and federal income tax, but the $500 pipeline cost-sharing incurs $105 additional tax so the benefit is reduced to $410. This, then, gives a final out-of-pocket cost of $5,830. The pipeline and turnouts have to be depreciated over their useful life of approximately 20 years. The economics of the project pointed clearly towards making the change but no one knows whether the farmer will continue with row crops or go back to pasture. As he himself said, "Promising to not go back to permanent pasture would be like promising not to get sick." Cost of chemical mosquito control for 1970 and 1971 was $384 and $562, respectively. Compare these figures with $22.60 received in 1971 from taxation for mosquito control.

Example 2.— Tailwater return system for a 20-acre parcel. About seven acres have been partially or entirely lost. Approximately one acre would be used as a sump and six acres would be returned to full production. Assume the six acres have a 50% increase in production, at $50/acre the total benefit would be about $150. The following figures are approximate estimates.

Cost of the pond, pump, pipe and facilities	$3,935
Cost-sharing	–1,228
Out-of-pocket expenditure	$2,707

Assume interest at 8%. This would amount to approximately $217 interest per year. With only $150 from increased yields, the project is not economically feasible.

The income tax situation does not help because only $650 of the total $3,935 is a deductible expense and this amount would be offset by an additional taxable income of $1,228 from cost-sharing. The remaining $3,285 would have to be depreciated over approximately 20 years at $164/year. Net taxable income would therefore be $347. Again, the biggest benefit from cost-sharing is in cash flow.

CONCLUSIONS.–Consideration of the various aspects of economics in source reduction leads us then to the following conclusions:

1. Cost-sharing by REAP produces taxable income but reduces the cash-flow problem.
2. Some projects can be justified on the basis of increased yields and this potential should be an effective argument for making improvements.
3. In certain cases, income tax laws can provide some incentive for the farmer to do source reduction work.
4. Land and improvement taxes may be incurred when source reduction increases the value of the property. In the public interest, there would be some merit in legislation that would provide additional property and income tax benefits to landowners or operators that make source reduction improvements at the request of a public agency.
5. Use of MAD equipment would be one of the best ways to do necessary work on uneconomical projects.
6. An uneconomical situation should not be a license to produce mosquitoes.

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THE FIRING LINE – WHAT'S GOING ON

George R. Whitten
Delta Mosquito Abatement District
1737 West Houston Avenue, Visalia, California 93277

"The firing line" sounds like we are opening up a new front in the war against mosquitoes, and we are!

That nebulous area where we work and where the general public lives and where the mosquito producer makes a living has always been a shifting kaleidoscope of financial burdens and responsibilities, legal rights, and moral obligations, and the question always arises as to who makes the decision, which belongs to whom.

For the last 25 years we have lived in the era of chemical control. With the exception of a few minor flurries in localized areas there has been little incentive to deviate very far from this obviously successful chemical approach to mosquito control. However, that sly mosquito and father time have called our number and whether we like it or not some major changes are in the offing.

Gentlemen, we have been in a rut over the past 25 years with our day to day chemical approach to mosquito control and you know what a rut is? A grave that is open at both ends. So it is about time we got out of it.

Many managers over the last 25 years have been chemically minded and to them and their boards of trustees a well organized spray program was the answer to mosquito control per se. This was justified by the limited budgets of many districts and unfortunately, the districts that needed relief from the overwhelming burden of a chemical program most had little money available for source reduction, or any other option which promised some permanent relief.

The variety of complex combinations of programs that will evolve over the next five years should be quite spectacular. Shifting from a chemical control program to the other options open to us will call for imagination and planning ability which should make complexity the order of the day.

Planning for this shifting program should be done on the basis of total needs. The groups in our local society which will be exerting pressure on our programs will see to it that we don't get too far out of line, but we should stay a step ahead of the pressures if we are going to be successful. The staffing of these new programs will require personnel with new skills and training programs can develop abilities in our existing personnel that we haven't used yet. The time element is very important. We are at the point now when this resistance crises could peak in the early part of the coming season. How much planning has been done? This shiftover should be accelerating, but is it?

The general public has been relatively free from mosquitoes for many years and likes it. It is ridiculous to think they will put up with the problem as it was before, or even slightly worse than it is, without repercussions. Phones will ring off the wall and hysterical women will get very hysterical.

The mosquito producer is the person we have to reach early enough to lessen the impact and give both of us time and opportunity to work out these problems.

The mosquito producer and agriculture in general is undergoing a major change from the small family farm to the large corporate entity. These large conglomerates should be easier to work with than the small farmer and are under more pressure to do the right thing because of their size and the fact that they have the financial muscle to do the regrading or install the irrigation or drainage system which is up to the modern standards necessary to solve our problem.

The importance of intelligent labor to operate these properly engineered farming enterprises is another factor which is only now being given the considerations it deserves. We have always been up against an unskilled or an overextended labor factor which has frustrated efforts to control areas which should never have been problems to begin with.

At this time we have the attention of the mosquito producer. The realization that this resistance problem is real is finally getting through to him. The ecology groups have already reached him with clean air, water and restricted chemical use and he doesn't want them to zero in on him for polluting the environment with mosquitoes. He is willing to make concessions which we can utilize to cure some of our basic problems such as regrading pastures, installing drain ditch and return systems and controlling the application of irrigation water.

This brings up the use of an equipment program as a supplement or a tool in the source reduction program of some districts. This has worked out very well for some districts and I think that these districts are well satisfied with the results of their equipment program. I know at Delta MAD we are sold on this approach.

The ability to make a positive suggestion to a farmer and then follow-through with the actual construction of the suggested structure or improvement has distinct advantages, for both the farmer and the District.

Many districts for the first time are seriously considering a source reduction program. This is a major change in a district program and will show very little positive mosquito reduction for the first few years. In the past many districts have been discouraged by this lack of progress these first years. This is a very normal situation which should be expected. The education of the new source reduction man and the education of the farmers in the district is no small matter and requires the application of much patience, persistence and planning.

Source reduction is by nature a long-term program and has many facets which must be used to complement each other. If we can handle these many facets intelligently they can help strengthen our program.

Education, of course, is basic and should be directed very specifically to the group or to the phase of the program which has a current need at the time. An example of this is the critical need to inform the general public far in advance to the buildup of resistance. This need has been recognized and is being attended to at this time. The approaching season will apprise us as to the success of our efforts in this direction. We have a critical need for the support of the general public to our coming season's program. There are bound to be many problems involved in our program changeover which will need understanding and patience by the public.

The second phase to our educational approach is to contact the mosquito producer. This is what Bob Turner and I are concentrating on now. There are no instantaneous results here either. Advance planning is the key and the fact that the district, the mosquito producer and the general public are intimately involved in the solution to the problem emphasizes the importance of stimulating some action.

We started a major shift to source reduction in the fall of 1969 at the Delta District. Bob Turner and I teamed up to contact our major mosquito producers on a yearly basis to present the resistance problem to the producer and ask for his help. When I say "ask" that is just what we have been doing. We haven't threatened or tried to coerce, but we haven't minced words or left any doubt as to who was responsible for the problem. The problem was placed before them and our first suggestion was to replace the pasture with another crop. In many cases this was not possible because of soil problems which make it impossible to grow any other crop on these alkali soils.

Our second suggestion was to regrade the pasture, install pipeline, drain ditches and a return system.

Of course we didn't expect these suggestions to be taken up immediately and of course they weren't, but as the pressure increases, and already it is being felt, we see more signs of these suggestions being implemented by actual changes. I believe very strongly that the farmer deserves a face-to-face contact with a district representative, and should have the opportunity to understand the problem thoroughly and the district's position and responsibility before any bills are submitted or legal action is instituted. When these steps are taken it is an admission that education, public relations, personal contacts and every other approach to the problem have failed.

To bring this paper to a close I would like to leave you with a few questions which we will all have to answer soon.

In our attempts to solve our problems is the objective only to gain attention to the mosquito problem or should we also consider the image we present to the farmer, the public and to our legislators?

As a basically technical association can we afford to build a loser image? Can we stand many adverse court decisions and can we afford to make demands that legally we can't back up? I wouldn't presume to try to answer these questions, but I do think that every district in the state should consider these questions very seriously before they reorganize their program in this direction.

I think we all remember Professor Herms and respect his broad outlook on mosquito control. I would like to quote from a paper on Public Relations given by Professor Herms at the 16th Conference of the CMCA in 1948:

"We should not forget that in the practice of mosquito control we are actually engaged in an education program and education is a slow process requiring much patience. Even the badge of your office, if authorized to wear a badge, should be used sparingly except as a means of identification. There are rare instances when you may need a badge of authority as a recognized procedure in gaining good public relations. Ordinarily the forceful use of authority to speed up a program only results in poor public relations."

NATURALISTIC APPROACHES: A PRACTICAL APPRAISAL

Robert D. Sjogren
Kern Mosquito Abatement District
P. O. Box 1271, Bakersfield, California 93302

In reviewing the program of the current session it was gratifying to see the increased emphasis on mosquito and natural predator biology, and potential means to manipulate these populations to our advantage. In presenting my views on naturalistic control approaches, I have chosen to discuss operational methods of predator-prey management available in the near future, a departure from the customary review of the annual status of potential biological control organisms. Let me be the first to concede that more work is needed before a managed and sophisticated biological control program can be integrated with most current operational programs. However, I believe the foundation needed on which to base such a program in seasonal waters has been laid during the past ten years, principally by University of California research workers.

Comprehensive predator-prey studies in rice field habitats by Washino (1968, 1969), Washino and Hokama (1967), and Ahmed et al. (1970) suggesting potential techniques for management of *Gambusia affinis* Baird and Girard), feeding habits (i.e., through crustacean population suppressive insecticide or algae control applications), and studies by Mulla (1961, 1966, 1970), Mulla and Isaak (1961), Mulla et al., (1966) and Hurlbert et al. (1970) on methodology for the integrated control of mosquitoes deserve particular praise. Recent work by Hoy et al. (1971) on the relationship of *G. affinis* population density and rice field mosquito control is equally valuable.

The successful utilization and manipulation of biological control organisms require a stable or semi-permanent environment, to permit predator-prey balances to establish. If mosquito breeding habitats are classified by duration into those in which water remains less than, and greater than a three-week period source reduction practices currently stand as the best remedial solution for the former. Regarding semi-permanent waters which do not lend themselves to source reduction of elimination measures, development of the necessary technology to obtain acceptable levels of mosquito control with minimal chemical treatment through management of predator-prey populations is foreseen within the next few years, via inoculative and inundative releases of mass produced natural predators functioning as semipermanent biotic insecticides.

The increased concern on the part of many mosquito abatement districts in the Central Valley, over insecticide resistance levels which make it difficult to obtain adequate levels of control with conventional phosphate insecticides, and the less pressing but equal desire for better control techniques at reduced cost, have in recent years brought about a reappraisal of many district programs.

Perhaps one of the greatest needs to obtain maximum benefit from current control practices is an in depth review and continued research on the ecological requirements and life cycles of target mosquito species during different months of the year. Such information has always been recognized as important, but I believe in most instances it has not given the depth of inquiry which it deserves.

As an example, in cooperative studies with Drs. Reeves and Hardy, University of California, School of Public Health, on the mechanisms of insecticide resistance, virus susceptibility and autogeny rates in field *Culex tarsalis* populations, marked differences were noted between collection areas. Varying levels of autogeny recorded from different locations throughout the season attracted particular attention. Autogeny rates during mid-season in many duck club and irrigation tail waters exceeded 80 percent. Lab dissections by Mr. Mike Winters revealed the fat bodies accumulated during larval development and carried over into the adult stage, which are used as an energy source for extended flight in search of blood by anautogenous females, are apparently metabolized in the development of the autogenous egg raft. Without this energy reserve, flights of any distance are unlikely. The question, why then control outlying *C. tarsalis* breeding areas during periods of high autogeny, was explored on an operational basis this past summer. While time was not available for a critical evaluation, over 3,000 acres were left untreated, without marked increases in adjacent light trap collections or service requests. Reduced gene flow between regional populations of this mosquito, if such exists, may also explain the mosaic pattern of greatly differing levels of insecticide resistance observed in adjacent field populations in areas of California.

Looking with optimism to the future, the Kern Mosquito Abatement District embarked during 1971 on a research program to develop the technology necessary for operational utilization of two predators considered to have the greatest potential as biological control agents of mosquitoes. Regarding the first, *Gambusia*, a fish planting device for attachment to the district's Bell 47G helicopter was designed, constructed and field tested, proving itself under operational conditions. Four anesthetics were screened for mass transport of *Gambusia*, the best being propoxate at 0.1–0.2 ppm. The fish trap (Caton & Sjogren, 1969) was further modified, as suggested by Mr. Thomas D. Mulhern from a cone to a vertical slit, yielding a 7-day mean catch of 7½ lbs. (5,310 fish).

Last spring an investigation was initiated to alleviate the annual problem of copper sulfate applications killing *Gambusia*, due to growers' practices of raising the application rate to its maximum (10lbs/ acre, i.e., approximately 7 ppm in the field water) in an effort to obtain better algae control. Publications of Ellms (1905) and Banerjea and Mitra (1954) demonstrated that copper sulfate was ineffective in killing algae even at concentrations as high as 10 ppm in alkaline waters due to precipitation of copper ions by hydroxide and carbonate ions.

Lab bioassays with chelated solutions of copper sulfate on *Gambusia* determined the combination producing the least mortality over a 24-hour period to be a ratio of 1:0.8 parts copper sulfate-citric acid (Table 1.). A subsequent 70-acre rice field application of this combination at a target concentration in the field water of 3 ppm copper sulfate, applied in a mixed fine crystalline form of each material in burlap bags suspended from weir boxes at approximate 15-acre increments, produced no *Gambusia* mortality, and in the opinion of the grower, a good level of algae control.

If further field trials confirm the greater algicidal efficacy of this combination in alkaline waters, and registration is available for this combination (each now individually approved), a potential material savings of in excess of $1.00 per acre would likely induce growers to convert to its use. The disadvantage of labor necessary to install commercially mixed and burlap bagged materials, at weirs within the field, is offset by avoided aerial application costs.

Hatchery feasibility studies are currently in progress to investigate the possibility of mass rearing *Gambusia* with the objective of providing a dependable source of the quantities desired for operational use. Initial emphasis is being placed on evaluation of mechanical separation devices to prevent adult predation of fry at birth, and maximum adult density levels under continual water exchange.

The second predator considered to have the greatest potential as a biological control agent is a backswimmer with a wide distribution in California, *Notonecta unifasciata* Guerin. This insect is under investigation in a cooperative study with Mr. Jack Hazelrigg, U.C. Riverside, to determine the shelf life of eggs of this species under cold storage. Notonectidae have been considered by many to be among the best invertebrate predators of mosquitoes (Hearle 1926; Hinman 1934; Clarke 1938; Lee 1967; and Ellis & Borden 1970), the 5 nymphal instars preying on larvae, as well as the adult. Reported predation rates vary with the species and temperature, averaging 30-50 per day. The life cycle and laboratory culture of *N. unifasciata* has been elucidated as a result of Mr. Hazelrigg's doctoral research. If the eggs of this family of insects can be stored at the correct embryological stage for 2-3 months, permitting colony mass production and subsequent refrigeration, this insect group may well earn a place in mosquito control equal to that of *Gambusia*.

In the end the maximum utilization of naturalistic methods for mosquito control will depend, as Dr. A. W. A. Brown has aptly put it, "on the knowledge, resourcefulness and persistence of the director of operations concerned".

Table 1.–Toxicity of copper sulfate to *Gambusia affinis* in combination with various concentrations of citric acid.[a]

Dosage (ppm) $CuSO_4$: Citric Acid	Average 24 Hour Percent Mortality
7.0 : 0	89
7.0 : 1.4	55
7.0 : 2.8	18
7.0 : 4.2	2
7.0 : 5.6	0
7.0 : 7.0	1

[a]Tests were conducted in gallon jars containing 3,000 ml of tap water at 75 ± 3° F. with 3 replicates of 8 fish/jar.

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OPERATIONAL EVALUATION OF FLIT® MLO IN THE ORANGE COUNTY MOSQUITO ABATEMENT DISTRICT IN JULY 1971

Gilbert L. Challet and Ralph F. Havickhorst

Orange County Mosquito Abatement District

P. O. Box 87, Santa Ana, California 92702

Flit® MLO has been used by the Orange County Mosquito Abatement District since 1968 on a continuous operational basis. In 1968 Flit MLO was evaluated in a ten square mile urban area in northern Orange County by Perruzzi (1970). Flit MLO was tested again in 1969 on a larger 32 square mile urban area which was 1/10 of the total urban area in the District. As the result of these evaluations, Flit MLO was used on the entire 320 square mile urban area within the District in 1970 (Kimball, 1970).

Because the District Control Operators felt that Flit MLO was not performing to expectations in several sources during the summer of 1970, an evaluation was proposed for the 1971 season. The purposes of this operational evaluation were then to determine the efficacy of Flit MLO in the operational zones of the District with their slightly different geographic and climatic conditions and to determine the cause of failures in these sources.

This evaluation was supposed to take place in July and August of 1971 which would be the District's months of highest mosquito production and highest temperatures. However, data from only July were gathered because August 1971 was the month when California was hit with the threat of Venezuelan Equine Encephalomyelitis and personnel were not available for this evaluation.

The investigation was designed to evaluate ten sources in each of seven of the District's eight operational zones, however, only six zones were evaluated. These sources were selected by the Vector Ecologist and the Zone Operator using the following criteria: source must be on a regular routine spray route, source should have continuous breeding, source should not be unique, and source should have no or very little running water. The seasonal operators doing the spraying were not advised that this evaluation was taking place.

Four qualitative and quantitative inspections of each of the 60 sources were made during the investigation; pretreatment, 24 hour post-treatment, seven days post-treatment and 13 days post-treatment.

Flit MLO was applied to all breeding sites located on public rights-of-way from an International Harvester Scout equipped with a 50 gallon pressure tank maintaining 40 psi at the nozzle. An application rate of two to three gallons of Flit MLO per acre to street gutters and roadside ditches was obtained by using a Spraying Systems Adjustable Cone

Table 1.—Summary of Results by Operational Zone.

Zone No.	Sources with good control	Sources with poor control	Total	Sources reduced	Total
2	7	0	7	3	10
4	8	1	9	1	10
5	9	1	10	0	10
6	8	2	10	0	10
7	6	1	7	3	10
8	7	2	9	1	10
Total	45	7	52	8	60
% of sources not reduced (52)	86.5%	13.4%	100%		

Jet Nozzle No. 5500-X3 set at its minimum discharge rate of 0.05 gpm and by driving at a speed of five mph. The nozzle was adjusted to its maximum setting of 0.20 gpm to produce a jet stream pattern for "slugging" the curb inlets to underground storm sewers as well as for reaching occasional sources located 10 to 15 feet from the vehicle. For off-street application, Flit MLO was applied by a two gallon hand spray can using the same pressure and nozzle.

Table 1 illustrates the efficacy of Flit MLO in the 60 sources were reduced and these were subtracted from the total of 60 sources to determine the percentage of sources showing good or poor control. Sources reduced means the source was altered in some way or dried up. Eighty-six percent (45/52) of the sources treated with Flit MLO showed good control, that is only 20 percent pupae or less 13 days after treatment. Only 13.4 percent (7/52) of the sources treated with Flit MLO showed poor control, that is sources having more than 20 percent pupae 13 days after treatment. The 20 percent pupae limit for the assessment of good control was set because Flit MLO will kill larvae and pupae.

Table 2 shows the source types that were sampled in each zone. Generally these were drains, ditches, catch basins and gutters. Drains and ditches were the predominant sources in this evaluation. Seven sources evaluated did not fit into a general description and these were a flood-retarding basin, an oil sump, a low area in a park where irrigation water collects, a creek, a sewage plant and two depressions.

The type and number of sources in which Flit MLO showed poor control is illustrated on Table 3. The failure of Flit MLO to work on these seven sources was due to one of three reasons. First, Flit MLO should not have been used on this particular source because source is not conducive to Flit MLO control. Secondly, the seasonal operator did not treat the source properly. Finally, Flit MLO just did not exhibit good control for 13 days when it should have.

The number of sources in which each mosquito species was found is shown on Table 4. These data indicate that *Culex peus* and *Culex quinquefasciatus* were found in over 65 percent of all sources. *Culex tarsalis* and *Culiseta incidens* were found in 30 percent and 21.6 percent of the sources, respectively. These four species were the only species found in this investigation. From these data it is obvious that more than one species occurred together in a source at one time.

Temperature and rainfall data for July 1971 is listed in Table 5. These data are from the Orange County Air Pollution Control District Headquarters in Anaheim. The mean daily temperature of 73°F compares very favorably with the past 20 years. Water temperature varied between 78°F and 92°F.

Kimball (1970) outlined the following three reasons for the use of Flit MLO in the Orange County Mosquito Abatement District:

1. The use of Flit MLO eliminates the hazard to the general public as well as to fish and wildlife.
2. The use of Flit MLO eliminates the toxic hazards to District employees.
3. The use of Flit MLO reduces the spray route man-hours and vehicle mileage up to 50% by increasing to 14 days the seven day spray cycle required for emulsions or granular type larvicides.

For these reasons and the data gathered on a District-wide basis in this evaluation, Flit MLO is an effective tool for mosquito control in urban community drainages in the Orange County Mosquito Abatement District.

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Table 2.–Number of sources inspected by type and zone.

	Source Types					
Zone Number	Drain	Ditch	Catch Basin	Gutter	Other	Total
2	2	2	5	0	1	10
4	0	6	0	3	1	10
5	4	3	1	1	1	10
6	0	6	1	3	0	10
7	6	2	0	0	2	10
8	8	0	0	0	2	10
Total	20	19	7	7	7	60
% of all sources (60)	33.3%	31.6%	11.6%	11.6%	11.6%	100%

Table 3.—Number of sources in which Flit® MLO showed poor control by type and zone.

	Source Types					
Zone Number	Drain	Ditch	Catch Basin	Gutter	Other	Total
2	0	0	0	0	0	0
4	1	0	0	0	0	1
5	0	0	0	0	1(park)	1
6	0	1	1	0	0	2
7	1	0	0	0	0	1
8	1	0	0	0	1(Dep)	2
Total	3	1	1	0	2	7

Table 4.—The number of sources in which each species was found.

	Species Incidence			
Zone Number	*Culex peus*	*Culex quinqs.*	*Culex tarsalis*	*Culiseta incidens*
2	10	5	0	0
4	7	6	6	2
5	4	10	3	6
6	7	9	5	0
7	8	3	2	0
8	5	7	2	5
Total	41	40	18	13
% of all Sources	68.3%	66.6%	30%	21.6%

Table 5.—Temperature and rainfall data – July 1971 Anaheim, California, Orange County.

Mean Daily Temperature	73°F
Mean Daily High Temperature	83.7°F
Mean Daily Low Temperature	62.6°F
Highest Daily Temperature	96°F
Lowest Daily Temperature	59°F
Rainfall	0.02 in.

EVOLUTION OF IMPROVED AERIAL APPLICATION TECHNIQUES FOR FLIT® MLO

G. V. Chambers
Esso Research and Engineering Company
P. O. Box 4255, Baytown, Texas 77520

ABSTRACT

Aerial application techniques for Flit® MLO are undergoing evolution. What is the basis for selecting the term, "evolution"? First, research findings to date exhibit a direction away from past practices. Second, the change in aerial application techniques is a process of evolution since the change is, in fact, a series of changes. Examples of change include:

1. Immature stage treated,
2. Swath width employed,
3. Inspection procedures,
4. Aircraft windshield washer, and,
5. Aircraft loading arrangements.

Further studies are in progress related to aerial application. Thus, change in aerial application techniques for Flit MLO will continue to evolve.

FIELD EVALUATION OF PETROLEUM OILS FOR THE CONTROL OF MOSQUITO LARVAE IN IRRIGATED PASTURES[1]

Husam A. Darwazeh[2] and Dennis Ramke[3]

INTRODUCTION.–The problem of mosquito resistance to insecticides in California in general and the Central Valley in particular is continuously spreading and becoming more critical annually. Organophosphorus larvicides are no longer effective means for mosquito suppression in many locations in California (Womeldorf et al. 1971). In Kings and Tulare counties, all available mosquito larvicides failed to render satisfactory control when applied by air as aqueous sprays or as ultra low volume sprays. These chemicals include ABATE®, Dursban®, EPN, fenthion, malathion, parathion, and methyl parathion. While not attributed to resistance, Flit® MLO also failed to achieve consistent and reliable control of mosquito larvae in irrigated pastures (Schaefer and Ramke, 1971; Gillies et al., 1971).

Mosquitoes in the multi-resistance areas are now being controlled in the adult stage with propoxur (Baygon®), usually formulated as a 70% wettable powder. Frequent use of propoxur will eventually lead to resistance buildup, with the likelihood that mosquitoes will be exceedingly difficult to bring under adequate control at a reasonable cost. Failures with propoxur have already been reported by several mosquito control agencies in the Central Valley. Further surveillance is necessary to confirm these reports. As long as propoxur is the only lethal weapon remaining, its use should be limited to emergency situations to safeguard the health of man and domestic animals.

The extensive development of mosquito resistance to organophosphorus compounds, carbamates, and chlorinated hydrocarbons has caused researchers to focus on resistance-proof materials with high biological activity against larvae of all species of mosquitoes. Several promising alternatives for mosquito control have been reported, but unfortunately these are largely in the early stages of development. These alternatives include attractants, ovicides, aliphatic amines, overcrowding factors, juvenile hormones, and larvicidal oils; other biological control agents, including pathogens, toxic algae, mustard seeds, and garlic extracts, are also being explored.

The studies reported upon here were undertaken to evaluate the effectiveness of several newly developed mosquito larvicidal oils under field conditions, and to determine the minimum application rates required to achieve adequate control.

METHODS AND MATERIALS.–Chevron 71R-2451 petroleum oil was applied by air in the Hahesy pasture southeast of Hanford in Tulare County. A Piper Pawnee PA-25 aircraft, calibrated to deliver one gallon of spray per acre at an estimated swath width of 60 feet, was used. At time of treatment there was no measurable wind, pasture vegetation

[1]The able assistance of Michael C. Gutierrez, California Department of Public Health, and the cooperation of the staffs of the Tulare and Kings Mosquito Abatement Districts is acknowledged.

California State Department of Public Health, Bureau of Vector Control and Solid Waste Management, 5545 East Shields Avenue, Fresno, California 93727.

[3]Tulare Mosquito Abatement District, P. O. Box 1476, Tulare, California 93274

ranged from medium to heavy in density, and from six to eight inches in height. Air temperature during the 24-hour duration of the test reached a high of 105°F during the day and dropped to 70° at night.

The mosquito population consisted of all aquatic stages of *Aedes nigromaculis*. Accordingly, the pasture was divided into four plots. Over Plot A, containing first and second instar larvae, four swaths (60 ft x ¼ mile) were applied, treating eight acres at the rate of one gallon per acre. Over Plot B, containing fourth instar larvae and pupae, seven swaths (60 ft x ¼ mile) were applied, treating 14 acres at the rate of one gallon per acre. Over Plot C, containing first and second instar larvae, 11 swaths (30 ft x ¼ mile) were applied, treating 11 acres at the rate of two gallons per acre. Plot D, containing first and second instar larvae, was left untreated as a check. Larval density was heavy throughout the field. Twenty dips were taken per plot before and 24 hours after treatment.

Chevron 71R-2451, Texaco Corvis, and Flit MLO petroleum oils were evaluated in Tulare County for the control of resistant *A. nigromaculis* and *Culex tarsalis* larvae in irrigated pastures. The petroleum oils reported on below were applied by a Piper Pawnee PA-25 aircraft calibrated to release ½ gallon of spray per acre at an estimated swath width of 60 feet.

Flit MLO, Texaco Corvis, and Chevron 71R-2451 were evaluated at the rate of 1.5 gallons per acre in the Gladney pasture, near Pixley in Tulare County. The mosquito population consisted of fourth instar *A. nigromaculis* larvae. Vegetation was dense and varied in height from six to 18 inches. Irrigation checks were 60 feet wide and ¼ mile long. Two adjacent checks were treated with each oil, with one check left untreated between plots to allow for drift and to avoid mixing. Each check was flown three consecutive times to apply 1.5 gallons per acre. Twenty dips were taken in each treated check before and 24 hours after treatement.

Flit MLO, Texaco Corvis, and Chevron 71R-2451 were also evaluated in the Lapadula pasture southeast of Tulare. The mosquito population consisted of all aquatic stages of *C. tarsalis*, and fourth instar larvae and pupae of *A. nigromaculis*. Irrigation checks in the pasture were 30 feet wide and ¼ mile long. Two adjacent checks were utilized per material, leaving two checks untreated as a buffer between treatments. The three oils were applied at two gallons per acre by flying each check twice. Twenty dips were taken per plot before and 24 hours after treatment, and the numbers of larvae and pupae of each species were recorded separately.

Chevron 71R-2451 alone was evaluated in the Okie Gay pasture, located two miles north of Pixley in Tulare County. The mosquito population, consisting of all aquatic stages of *C. tarsalis*, was concentrated in large numbers in cattle hoofprints and in the lower end of the field where water accumulates and seldom dries between irrigations. Vegetation density was light and ranged from two to ten inches in height. Five swaths (60 ft x ¼ mile) were applied, and each swath was flown four times to deposit two gallons per acre. Forty dips were taken across the treated area before and 24 hours after treatment.

RESULTS AND DISCUSSION.—All of the petroleum oils tested failed to achieve any measurable control of *C. tarsalis* larvae in Tulare County when applied by air at the rate of two gallons per acre (Table 1). At the same rate, however, Chevron 71R-2451 and Texaco Corvis rendered 63% and 50% reduction, respectively, of the *A. nigromaculis* larvae. Chevron 71R-2451 also achieved 56% reduction, while Flit MLO and Texaco Corvis oils failed against *A. nigromaculis* larvae at the rate of 1.5 gallons per acre (Table 2). In Kings County Chevron 71R-2451 achieved complete control of the immature stages of *A. nigromaculis* at the rate of two gallons

Table 1.—Evaluation of various petroleum oils for the control of *Culex tarsalis* larvae in irrigated pastures at the rate of two gals/acre (Tulare County 8/31/71).

Petroleum Oil	Avg. No. of Larvae/Dip[c] Pre-Treatment	Post-Treatment	Percent Reduction
Chevron 71R-2451[a]	30	33	0
Check	25	36	0
Chevron 71R-2451[b]	11	13	0
Texaco Corvis	5	14	0
Flit® MLO	2	6	0
Check	8	9	0

[a]Okie Gay pasture.
[b]Lapadula pasture.
[c]Third and fourth instar larvae.

Table 2.—Evaluation of various petroleum oils for the control of fourth instar larvae of *Aedes nigromaculis* in irrigated pastures[a] (Tulare County 8/31/71).

Petroleum Oil	Dosage gal/acre	Avg. No. of Larvae and Pupae/Dip Pre-Treatment	Post-Treatment	Percent Reduction
Flit® MLO	1.5	3		b
Flit® MLO	2.0	8	18	0
Chevron 71R-2451	1.5	41	18	56
Chevron 71R-2451	2.0	19	7	63
Texaco Corvis	1.5	12	12	0
Texaco Corvis	2.0	4	2	50
Check A		3	5	0
Check B		15	36	0

[a]The 1.5 gal/acre rate was applied in Gladney pasture, and the 2.0 gal/acre rate was applied in Lapadula pasture.
[b]The checks were reflooded during the night prior to the post-treatment count.

per acre (Table 3). Owing to evaporation, larvae tended to be more densely concentrated in the remaining water. Post-treatment counts were therefore higher in some instances than those of the pre-treatments, even though some larval mortality could have occurred (Table 1).

While Flit MLO is being used successfully as mosquito larvicide by several mosquito abatement districts in California, it failed to render any measurable degree of control in Tulare County. Chevron 71R-2451 achieved excellent results in Kings County but failed in the Tulare area. It has been theorized that these failures may be attributable to water quality, water pH, soil pH, soil type, accumulation of fine foreign organic particles on water surfaces which prevented the oil film from spreading, or the presence of unusually hardy and adaptable mosquito populations in the area.

Field evaluations by various mosquito control agencies in California have shown Flit MLO to achieve mosquito suppression three to four days after treatment. Flit MLO at times appeared to delay the development of immature stages, and the water in the treated area in some instances disappeared before any adult emergence could occur. It is possible, therefore, that these petroleum oils might appear to perform better in Tulare County if the period of post-treatment observation were extended beyond 24 hours. However, the purpose here was to compare the results of newly developed petroleum oil with a well established oil, hoping for an effective and fast acting material that could be used in the control of multi-resistant larvae in irrigated pastures.

Table 3.–Evaluation of petroleum oil (Chevron 71R-2451) for the control of larvae of *Aedes nigromaculis* in irrigated pastures (Kings County 7/21/71).

			Avg. No. of Larvae/Dip		
Plot Number	Dosage gal/acre	Development Stage	Pre-Treatment	Post-Treatment	Percent Reduction
A	1.0	1-2	14	3	79
B	1.0	4-P	3	0.6	80
C	2.0	3-4	22	0	100
Check		1-2	18	21	0

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EFFICACY OF FORTIFIED PETROLEUM OILS AS MOSQUITO LARVICIDES IN IRRIGATED PASTURES

Husam A. Darwazeh[1], Richard C. Fox[2] and Dennis J. Ramke[3]

Several larvicidal petroleum oils were evaluated for the control of the multi-resistant mosquito larvae *Aedes nigromaculis* and *Culex tarsalis* in irrigated pastures (Darwazeh and Ramke 1972). Excellent results were achieved with Flit® MLO and Chevron Research 71R-2451 in Kings County at the rate of two gallons per acre, but at the same rate these oils failed to render acceptable control in Tulare County. Schaefer and Ramke (1971) and Gillies et al. (1971) also failed to achieve consistent larval suppression with Flit MLO in irrigated pastures at the rate of two gallons per acre.

[1]California State Department of Public Health, Bureau of Vector Control and Solid Waste Management, 5545 East Shields Avenue, Fresno, California 93727.

[2]Chevron Research Company, 576 Standard Avenue, Richmond, California 94804.

[3]Tulare Mosquito Abatement District, P. O. Box 1476, Tulare, California 93274.

[4]Manufactured by California Laboratory Equipment Company, 1717 Fifth Street, Berkeley, California.

Failure to control larvae in Tulare irrigated pastures with Petroleum oils or any other known mosquito larvicide represents a problem of genuine concern to the inhabitants of the area and the surrounding communities; therefore, an effective mosquito control agent is essential and needed immediately.

The present studies were initiated to determine the susceptibility level of mosquito larvae from various areas to petroleum oils, to establish the feasibility of enhancing the effectiveness of readily available oils through fortification, and to evaluate newly formulated fortified petroleum oils in the laboratory and under field conditions for the control of resistant mosquito larvae in irrigated pastures.

METHODS AND MATERIALS—Laboratory Evaluation.—White enamel pans, 800 cm^2, were lined with aluminum foil, and 20 fourth instar larvae were placed in each pan containing 2,000 ml of water. The petroleum oils were applied with a Calab microsyringe, 2,500 micrometer unit[4] and mortality readings were obtained 24 hours after treatment. Second instar *A. nigromaculis* larvae utilized in the

Table 1.–Laboratory evaluation of fortified petroleum oils against two species of fourth instar mosquito larvae (Fresno, 9/29/71).

Petroleum Oil[a]	Dosage gal/acre	Dosage µl/cm²	Avg. (percent) Mortality *Culex pipiens quinquefasciatus*	*Aedes nigromaculis* Tulare	*Aedes nigromaculis* Kings
Chevron Research 71R-2493	0.5	20	5	0	5
Chevron Research 71R-2493	1.0	40	10	10	10
Chevron Research 71R-2469	0.5	20	95	50	32
Chevron Research 71R-2469	1.0	40	100	60	88
Chevron Research 71R-2469B	0.5	20	95	20	32
Chevron Research 71R-2469B	1.0	40	100	40	80
Golden Bear-1198	0.5	20	100	60	50
Golden Bear-1198	1.0	40	100	70	90
Check			0	0	0

[a]These were experimental oils fortified by the suppliers with various additives and surfactants.

Table 2.–Field evaluation of fortified petroleum oils for the control of *Aedes nigromaculis* larvae in irrigated pasture (Tulare County, 9/28/71).

Chemical & Formulation	Dosage Pet. Oil gal/acre	Dosage Fenthion lb/acre	Avg. No. of Larvae/Dip[a] Pre-Treatment	Avg. No. of Larvae/Dip[a] Post-Treatment	Percent Reduction
Fenthion EC7 in	0.5	0.1	15	26	0
Chevron Research 71R-2451	1.0	0.1	43	96	0
Check			22	34	0

[a]Population consisted of third to fourth instar larvae.

tests were collected from the Hoffman pasture in Tulare County and the Costa pasture in Kings County. Mosquito larvae in both areas are known to be highly resistant to all available organophosphorus mosquito larvicides and chlorinated hydrocarbons. *Culex pipiens quinquefasciatus* larvae were obtained from a susceptible strain of an autogenous colony maintained in the laboratory at Fresno.

Field Evaluation.–Thirty-two ounces of fenthion EC7 were mixed in 15 gallons of petroleum oil (Chevron Research 71R-2451), and applied at the rate of 0.1 pound of active ingredient (a.i.) of fenthion in 1.0 gallon of oil per acre. Eight swaths were applied (30 ft x ½ mile) treating 15 acres. Sixteen ounces of fenthion EC7 were also mixed with 15 gallons of Chevron Research 71R-2451 and applied at 0.1 pound (a.i.) fenthion in ½ gallon of oil per acre. Eight swaths were made (60 ft x ½ mile) covering 30 acres. Tests were conducted in the Visbeek pasture in Tulare County. The materials were applied by air with a fixed wing Piper Pawnee PA-25 aircraft which was calibrated to release ½ gallon of spray per acre at an estimated swath width of 60 feet. The mosquito population consisted of third and fourth instar larvae of *A. nigromaculis*. Forty dips were taken per plot before and 24 hours after treatment.

Chevron Research 71R-2493 with and without 5% Duomeen T® was evaluated in the Hoffman pasture in Tulare County. A helicopter, Enstrom F-28A, was used for oil application, covering 75 feet per swath, and delivering 0.5 gallon per acre. In order to apply 1.0 and 2.0 gallons per acre, each swath was flown twice or four times to apply the desired rate. Mosquitoes in the pasture consisted of all the aquatic stages of *A. nigromaculis*, and 20 dips were taken across each plot before and 24 hours after treatment. Eight acre plots were treated with 1.0 and 2.0 gallons per acre with Chevron Research 71R-2493, and 16 acres were treated with the same material containing 5% Duomeen T at the rate of 1.0 gallon per acre.

Table 3.—Field evaluation of fortified petroleum oils for the control of *Aedes nigromaculis* third to fourth instar larvae in irrigated pastures (Tulare County 9/29/71).

		Avg. No. of Larvae/Dip		
Chemical & Formulation	Dosage gal/acre	Pre-Treatment	Post-Treatment	Percent Reduction
Chevron Research 71R-2493	1.0	101	33	68
	2.0	30	22	27
Chevron Research 71R-2493 with 5% Duomeen T	1.0	51	83	0
Check		35	56	0
Chevron Research 71R-2451 with 5% Duomeen T	1.0	156	7	96
Check		168	175	0

Chevron Research 71R-2451 containing 5% Duomeen T was evaluated in the Faria pasture in Tulare County. Second and third instar larvae of *A. nigromaculis* were extremely numerous and distributed throughout the entire field. Irrigation checks were 75 feet in width and ¼ mile in length; therefore, each check was flown twice with the helicopter, treating 25 acres at the rate of 1.0 gallon per acre. Forty dips were taken prior to and 24 hours after treatment across the field.

Results and Discussion.—All the petroleum oils evaluated in the laboratory displayed high biological activity against the susceptible strain of *C. p. quinquefasciatus* with the exception of Chevron Research 71R-2493. Complete larval mortality was obtained with Golden Bear Oil-1198 at the rate of 0.5 and 1.0 gallon per acre, and at the same rate, Chevron Research 71R-2469 and 71R-2469B were equally effective and achieved 95% and 100% mortality. Against the multi-resistant pasture mosquito larvae, *A. nigromaculis*, none of the oils evaluated achieved complete larval mortality at the rate of 1.0 gallon per acre. Larvae obtained from Kings County were more susceptible to the oils than those obtained from Tulare County (Table 1). Further detailed studies, however, are needed to confirm these findings.

Results of the field evaluation of fortified petroleum oils against multi-resistant larval *A. nigromaculis* were discouraging. One gallon of Chevron Research 71R-2451 containing 0.1 pound (a.i.) of fenthion failed to control mosquito larvae when applied by air in irrigated pasture (Table 2). Chevron Research 71R-2493 with 5% Duomeen T was effective against the pupae, but failed to control the larvae at the rate of one gallon per acre. At the same rate, however, Chevron Research 71R-2451 with 5% Duomeen T rendered 96% reduction in the larvae (Table 3). Due to the density of the mosquito larvae in the pasture, 96% reduction in the population was not sufficient to achieve adequate control. The surviving larval population was high (7 per dip), and necessitated additional treatment. According to field tests by several mosquito abatement agencies in California, petroleum oils such as Flit MLO, at times appeared to delay the development of immature stages and the water in the treated area in some instances disappeared before any adult emergence could occur. It is possible, therefore, that these oils could have been shown to perform better if the period of post-treatment observations was extended beyond 24 hours. In the search for a quick and effective material for a quick and effective material for the control of the resistant mosquito larvae, observations beyond 24 hours after treatment were ignored even though reduction in the adult emergence rate could have been achieved. These studies were initiated toward the end of the mosquito breeding season in irrigated pasture; therefore, ideal fields were unavailable for further evaluation of these formulations at a higher rate to determine the minimum amount required to achieve adequate mosquito larvae control.

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STUDIES WITH A JUVENILE HORMONE ANALOGUE FOR THE CONTROL OF *CULEX PIPIENS QUINQUEFASCIATUS* SAY

Leyburn F. Lewis and Darrell M. Christenson

United States Department of Agriculture

Agricultural Research Service, Entomology Research Division, 5544 Air Terminal Drive, Fresno, California 93727

During the last few years the juvenile hormone analogues have emerged as a very promising group of chemicals for the control of mosquitoes (Jakob and Schoof, 1971). Various companies are synthesizing new analogues and making available limited quantities of those that offer the most promise.

At the USDA's Western Insects Affecting Man and Animals Laboratory in Fresno we have worked for about two years with various juvenile hormone analogues. Some, including ENT 70357 (E)-4-[(6,7-epoxy-3,7-dimethyl-2-nonenyl)oxy]-1,2-(methylenedioxy) benzene, (Hoffman-La Roche, Inc. R020-3600[1], first described by Bowers, 1969) which will be reported on here, show considerable promise for the practical suppression of mosquito emergence when the larval state is treated.

Since the juvenile hormone analogues primarily function as hormones and not as toxicants, the approach to their evaluation has to be somewhat different from the approach to the evaluation of toxicants. The analogues we have tested have had certain characteristics in common in so far as mosquito larvae were concerned. First, all have exhibited a rather short half-life in larval rearing water. Secondly, as agents that suppress emergence they apparently exert their effect only through larvae that are in the fourth instar. Therefore, when younger instars are treated, enough material must be used to assure that an effective residual titer is in the water when the larvae have developed to the fourth instar. Considering the short half-life of the analogues then, and assuming uniform rearing conditions, more material is required to obtain control when they are treated in the first, second, or third instar than to get control when they are treated in the fourth instar (Table 1). Mortality due to hormonal action in any case occurs in the pupal rather than in the larval stage. So when evaluating the juvenile hormone analogues, non-emergence of viable adults is the criterion of control.

[1]Mention of a commercial or propriety product in this paper does not constitute an endorsement of this product by the USDA.

Table 1.–Results of one-treatment laboratory and semifield bioassays of ENT 70357 applied to the rearing water of *Culex pipiens quinquefasciatus* Say.

	Emergence pattern at indicated treatment concentration[a]			
	1st Instar		4th Instar	
ppm	laboratory[b]	semifield[c]	laboratory[b]	semifield[c]
1.0	0	+	0	0
.1	0	+	0	0
.05	0	+	0	0
.025	0	+	0	0
.01	0	+	0	+
.005	+	+	0	+
.003	+	–	0	–
.001	+	–	0 to +	–
.0005	+	–	+	–
Control	+	+	+	+

[a]0 = No emergence observed. + = good emergence observed.
[b]Temperature 78° ± 1° F.
[c]Daily maximum temperature generally 100° F or higher.

MATERIALS AND METHODS.–The laboratory treatments reported on here were run in 250 milliliters of water in pint jars. No water was added after the dosages were applied. *Culex pipiens quinquefasciatus* Say were used and the first and the fourth instar were tested separately. From 100 to 125 larvae were used in each jar with a minimum of two replicates per dosage in each test. Larvae in all tests were fed as needed. Technical material in ethyl alcohol generally was used, but acetone served equally well as a solvent. Artificial illumination was used in the test room with a light phase of 16 hours. Temperature was held at a constant 78° ± 1°F. Judgments on efficacy were based solely on successful adult emergence. Since the emphasis in this paper is directed towards semifield tests, data from laboratory tests are included for comparative purposes only.

The simulated field work was performed in our small cooperative pasture at Fresno State College. Tests were made in two liters of water in 82 oz white plastic containers. Water volume was maintained by additions at two to three day intervals. Water with food added had stood in each container for several days before the container of water was used in a test. Water added during a test also had stood in white plastic containers for several days. Larvae of *C. p. quinquefasciatus* were used with treatments assigned at random. As in the laboratory, judgments on efficacy were based solely on adult emergence.

RESULTS AND DISCUSSIONS.–Under the conditions prevailing in our laboratory 0.003 ppm of ENT 70357 was the lowest dosage that consistently gave 100% control with fourth instar larvae (Table 1). Lower dosages on occasion gave complete or a high degree of control, but in other tests those same dosages gave little to no control.

Data obtained from tests with intermediate instars are not presented in tabular form, for comparable tests were not made in the field; but in comparative tests in the laboratory higher dosages were required for control with intermediate than with fourth instar larvae, and lower dosages were required for control with the intermediate than with the first instar larvae.

With first instar larvae in the laboratory, 0.01 ppm was the lowest dosage that consistently gave 100% control (Table 1). With first instar larvae, constancy in degree of control with minimal dosages could be highly correlated with the total length of the larval cycle starting from the time of treatment. Unless precise rearing procedures and timing in administering treatments were followed (such as, for example, always treating just-hatched larvae or always treating larvae that were 24 hours of age) some degree of variability in percent mortality generally resulted.

In the laboratory, dosages of technical material, a 25% emulsion concentrate, and a 50% emulsion concentrate gave similar results.

In our initial semifield tests we were after information on the effectiveness of a single-dose treatment against a mixture of all instars, but primarily against the first and fourth instars. At the same time we preferred to closely emulate actual field conditions. Prior to the tests then, we determined from several locations that wild females actually would oviposit in the 32 oz test containers. The initial test – not presented here in tabular form – was in containers which, with water and larval food added, had stood in open sunlight until a biotic equilibrium appeared to have been reached. The water levels were then accurately readjusted, larvae of all instars added, and treatments applied. But despite the initial addition of food, the influx of a considerable amount of leafy material before the test started, insects that drowned, a heavy algal growth, other miscellaneous contaminants that undoubtedly were a source of food, and 100°F or higher daytime temperatures, larval development was so prolonged and uneven that after three weeks the test was terminated with very little observed mortality and with considerable numbers of larvae still in the second and third instars. Subsequent tests, using the same procedure, yielded similar results. In fact the observed developmental time span was very similar in several other situations in both similar and larger containers where wild females had oviposited in continuously standing water. We therefore are inclined to regard the observed developmental times as being somewhat typical for the species in containers in the Fresno area.

We then ran a series of tests involving rearing procedures, test sites, and other variables. From this series we determined that a given number of just-hatched larvae, when fed at two-day intervals, would produce within eight days a fairly high percentage of large, vigorous pupae and the beginning of adult emergence. Also, developmental time proved to be comparable in screened houses, in full sunlight, and in partial sunlight. In order to minimize adult escapement, then, the remainder of the tests were run in screened houses.

Somewhat better results, not presented here in tabular form, were obtained with technical material than with the emulsion concentrate we had on hand. Technical material in ethyl alcohol therefore was used during the remainder of the test.

Even with the speeded up rearing procedures, however, ENT 70357 against fourth instar larvae (Table 1) did not perform as well in the simulated field tests as in the laboratory by a factor of about eight. But by any realistic standard the lowest dosage that did give control with the fourths, 0.025 ppm, offered great promise for the practical control of the species. Although at dosages up to one ppm – the highest tested – ENT 70357 had not retained its effectiveness long enough in the hot prevailing temperatures to give appreciable control when applied to the first instar, considering the very promising results with the fourth instar larvae, further testing was obviously warranted.

As an alternative to the one-treatment concept we decided to run tests in which periodic treatments were administered to larvae under conditions of continuous rearing. Our test concentrations were 0.025 and 0.05 ppm with each dosage replicated five times. All larval instars were present at the time of the initial treatment, and about 150 first instar larvae per container were added twice weekly. The natural deviations in growth rate that occur in most batches of larvae tended to assure a continuous supply of adequate numbers of all larval instars and maintain the standing population to the carrying capacity of the containers. On those occasions when a marked imbalance did occur in instar ratio in any container, however, an acceptable balance was restored by the addition of other instars. Some larval food was added about every two days and the water volume was maintained with considerable accuracy. From the time of initial pupation, good numbers of large, vigorous fourth instar larvae and pupae were present throughout the test.

Good success occurred throughout the 34 days of the periodic treatment test. Although the original plan called for treatments at five-day intervals, the results were so favorable after the first two applications that the interval was lengthened to six days. No emergence from the treated containers was observed during the period of the six-day-interval treatments, but an occasional partial emergence in the 0.025 ppm segment of the test indicated that further extension of the interval at that concentration or a further lowering of the dosage would probably result in emergence. Almost continuous emergence occurred from all five untreated controls.

We concluded from these results that ENT 70357 had real promise for the practical control of mosquitoes in the field. But since we had started the periodic treatments during the last days of August, and much of September was gone before the evaluation was complete with the six-day interval applications, further testing outdoors in 1971 was considered impractical. Much work obviously remains to be done, however, under a wide variety of actual field conditions, in testing against other species and genera of mosquitoes, in different types of formulations and in timing of applications.

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A PRACTICAL EVALUATION OF INSECT DEVELOPMENTAL INHIBITORS AS MOSQUITO CONTROL AGENTS

Charles H. Schaefer and William H. Wilder
University of California
Mosquito Control Research Laboratory, 5545 East Shields Avenue, Fresno, California 93727

ABSTRACT

The term, "insect developmental inhibitor", is proposed to describe compounds having biological activity that mimics that of natural, insect, juvenile hormones and that are being evaluated as insect control agents. There is much greater variation in mortality between replicate tests run at different times than is typical for classical insecticides. The sensitivity of larvae to a given compound varies with age in the fourth stage; the earlier larval stages are less sensitive than the fourth. Several compounds produced very high rates of mortality in both laboratory and field evaluations. One of these, ZR515, had a high degree of activity on *Aedes nigromaculis* (Ludlow) larvae at .00001 ppm in the laboratory and gave encouraging results at 0.125 lbs/acre in the field. Another, R020-3600, also showed high activity in the laboratory and in the field with the same species at rates as low as 0.25 lbs/acre. MON-585, whose structure is dissimilar to known natural, insect hormones, gave excellent control of *A. nigromaculis* larvae in field tests where 1.5 or 2.0 lbs/acre were applied by helicopter.

MOSQUITO ADULTICIDING WITH SYNERGIZED PYRETHRUM

Joseph E. Lee
McLaughlin Gormley King Company
1715 East Fifth Street, Minneapolis, Minnesota 55414

All of us like to talk about something that's new and exciting. Pyrethrum is not new by any stretch of the imagination, but its rediscovery in mosquito control is exciting.

As you know, pyrethrum has long been recognized for its effectiveness against mosquitoes. It was one of the early insecticides used for larviciding in New Jersey before World War II. You're aware, of course, that it has been used in aerosol cans, non-pressurized sprays, and emulsions for mosquito control in homes, resorts, restaurants and institutions for many years, but it's been years since it has been considered for area mosquito adulticiding.

The advent of commercial cold aerosol equipment has made it possible for synergized pyrethrum to be used at realistic economic levels in mosquito adulticiding in ground equipment.

The safety of synergized pyrethrum is well documented. According to Volume 3 of the Handbook of Toxicology, the LD_{50} for pyrethrum ranges to 1500 mg/kg and piperonyl butoxide, the synergist we've used with it in mosquito control, has an LD_{50} of 7500 mg/kg. Pyrethrum's non-persistence was a curse for many years. Now we find we're wearing the white hats instead of fighting off brickbats because of its non-persistence –– and I can tell you –– this is more fun. Its non-persistence and low toxicity to humans, birds and to bees (Anderson et al. 1971) make it an excellent insecticide to use in area treatment. Fear about drift into non-target areas is minimized because of its low toxicity and non-persistence.

Synergized pyrethrum offers several advantages in adulticiding. These are:

1. the inherent safety of pyrethrum and piperonyl butoxide;
2. freedom from concern about drift; although pyrethrum is toxic to fish the dosage rate is such that chances of killing fish with pyrethrum in mosquito adulticiding programs are nil;
3. relatively non-toxic to honey bees, as just indicated;
4. exemption from tolerances on all growing crops; and
5. rapidity of degradation under field conditions.

This past year we cooperated in field adulticiding tests using pyrethrum and piperonyl butoxide in cold aerosol equipment in four geographic locations. Here in California, work was done with the Micro-Gen unit. In Florida and Maryland work was done with the Leco unit and in Minnesota work was done with both the Leco and the Hudson Backpack. Application rates ranged from .002 pound to .005 pound per acre pyrethrins and five times those levels of piperonyl butoxide. As a result of the success of this work we expect some commercial applications of pyrethrum and piperonyl butoxide during 1972 for mosquito adulticiding. Table 1 shows a summary of the results of the 1971 tests on both caged and uncaged mosquitoes.

The uncaged mosquito test was performed under A. W. Buzicky's direction in Minnesota and will be presented in greater detail at the Florida meeting of the AMCA by Mr. Buzicky. The Maryland work was conducted under the direction of Dr. Robert Altman. I do not know whether Dr. Altman intends to present a formal report at any meeting.

In work done in the southeastern United States in 1970 and 1971 a further benefit of using pyrethrum and piperonyl butoxide was noted. Control of Chrysops was observed by Dr. Theodore R. Adkins, Jr. of the Department of Entomology and Zoology of Clemson University of Clemson, South Carolina. He reported on this work at the recent Entomological Society of America meeting in Los Angeles (Table 2.)

In 1972 we hope to fill some gaps in our test results. Only a modest amount of work was done in the past year with aircraft application of synergized pyrethrum. Further ground cold fog work will be done also in a number of states.

The relative toxicity of pesticides to honey bees as deter-

Table 1.–Effectiveness of synergized pyrethrins as a mosquito adulticide.

A. Upper Midwest – HUDSON no. 4712 BACK PACK – Free-Flying, Natural Infestations.

	Pounds per Acre		Acres	Bites per Minute				
Site	Pyns	Pip. But.	Treated	Pre-Treat	2 Hr.	4 Hr.	24 Hr.	Species
1	.005	.025	1	5	0		5	*Aedes vexans*
2	.005	.025	6	12	0		7	*Mansonia perturbans*
3	.0025	.0125	1	5		0	2	*Aedes vexans*
4	.0025	.0125	3	9	1	0	4	*Aedes vexans*
5	.0025	.0125	7	5	1		6	*Aedes vexans*
6	.0025	.0125	4	6	1		2	*Aedes* species

B. Mid Eastern Seaboard Region – LECO ULV Cold Aerosol Generator, Model HD – Caged Adult Female *Culex pipiens*.

Number	Pounds per Acre		Average Percent Knockdown and Mortality											
			50 Feet			100 Feet			200 Feet			300 Feet		
Tests	Pyns	Pip. But.	1 Hr.	8 Hr.	24 Hr.	1 Hr.	8 Hr.	24 Hr.	1 Hr.	8 Hr.	24 Hr.	1 Hr.	8 Hr.	24 Hr
3	.0084	.0420	100	100	100	99	100	100	100	100	98	100	100	99
3	.0019	.0095	100	100	100	100	100	99	97	99	89	94	97	90

C. Florida – LECO ULV Cold Aerosol Generator, Model HD – Caged Mosquitoes – Single Test – Average Mortality in Cages at 150 feet and 300 feet.

Percent Mortality after 18 Hours at Indicated Dose (pounds per acre)		
Pyrethrins	.006	.003
Piperonyl butoxide	.030	.015
	84%	74%

D. California – Jeep-Mounted MICROGEN – 4 nozzle – Caged *Culex pipiens*.
Dosages: 1% Pyrethrins + 5% Pip. But. – 20.3 fl. oz/min.
5% Pyrethrins + 25% Pip. But. – 41.8 fl. oz/min.

	Percent Mortality – 24 Hours at Distances Shown from Unit				
	500 Ft.	1000 Ft.	2000 Ft. 2000 Ft.	2500 Ft.	3000 Ft.
1% Pyns + 5% Pip. But.	96	83	62	4	8
5% Pyns + 25% Pip. But.	100	100	96	94	87

Table 2.–Reduction of deer flies (*Chrysops*) in recreational areas with synergized pyrethrins.[a]

	Avg. No. deer flies per trap per day	
	Treated Area	Untreated Area
Four days prior to treatment	139	149
First day post-treatment	21	85
Second day post-treatment	31	84

[a]Southeastern U. S. seaboard region, free-flying natural infestations *Chrysops niger*, truck-mounted Microgen, 4-nozzle equipment, using 5% pyrethrins plus 25% piperonyl butoxide, 1280 fl oz applied in 58 minutes over a distance of 5.8 miles.

mined by laboratory and field tests in California (1950-1971) is shown in Table 3. Pyrethrum appears in the section of the table entitled "Relatively Non-toxic" whereas the insecticides most commonly used to control mosquitoes appear in the "Highly Toxic" section.

Under the direction of Dr. Mir Mulla a series of synergized pyrethrum applications was made in Kern County on

Table 3.–Relative toxicity of insecticides to bees.[a]

Group 3–RELATIVELY NONTOXIC: These can be used around bees with a minimum of injury.

Acaraben® (chlorobenzilate)	Morestan®
Allethrin	Morocide® (binapacryl)
Aramite®	Murvesco® (fenson)
Bacillus thuringiensis	Nemagon®
cryolite	Neotran®
Delnav® (dioxathion)	nicotine
Dessin®	Omite®
Dilan®	OMPA (schradan)
Dimite® (DMC)	Ovotran® (ovex)
DNOCHP (dinitrocyclohexyphenol)	Phostex®
Dylox® (trichlorfon)	pyrethrin
Eradex®	rotenone
Ethodan® (ethion)	Rhothane® (TDE)
Fundal®, Galecron® (chlorophenamidine)	ryania
Heliothis virus	sabadilla
Kelthane® (dicofol)	Saphos® (menazon)
Kepone®	Strobane®
methoxychlor	Sulphenone®
Mitox® (chlorbenside)	Tedion® (tetradifon)
	toxaphene

[a]Anderson, L. D., Atkins, E. L. Jr., Nakakihara, H., E. A. Gregwood, 1971. Toxicity of pesticides and other agricultural chemicals to honeybees, field study. University of California bulletin AXT-251, Rev. 6/71, p. 3.

Group 2–MODERATELY TOXIC: These can be used around bees if dosage, timing, and method of application are correct, but should not be applied directly to exposed bees in the field or at the colonies.

ABATE®, Biothion®	Meta-Systox R® (oxydemetonmethyl)
Agritox®	mirex
Banol®	Perthane®
Carzol® (formetanate)	Phosalone®
chlordane	Phosvel® Abor®
Ciodrin®	Pyramat®
Co-Ral® (coumaphos)	Systox® (demeton)
DDT	tartar emetic
Di-Syston® (disulfoton)	Thimet® (phorate)
endothion	Thiodan® (endosulfan)
endrin	Trithion® (carbophenothion)
Korlan® (ronnel)	
Meta Systox® (methyl demeton)	

Group 1–HIGHLY TOXIC: Severe losses may be expected if the following materials are used when bees are present at treatment time or within a day thereafter, except as indicated by footnotes.

aldrin	Furadon®
arsenicals	Gardona®
Azodrin® (crotonamide)	Guthion® (azinphosmethyl)
Baygon®	heptachlor
Baytex® (fenthion)	Imidan®
BHC	Lannate® (methomyl)
Bidrin®	Lindane
Bux® (RE-5353)	malathion
Chlorthion®	Matacil®
Cygon®, DE-FEND® (dimethoate)	Mesurol®
Dasanit® (fensulfothion)	Metacide®
DDVP (dichlorvos)	methyl parathion
diazinon	Methyl Trithion®
Dibrom® (naled)	Mobam®
dieldrin	Monitor®
Dimecron® (phosphamidon)	parathion
Dursban®	Phosdrin® (mevinphos)
EPN	Sevin® (carbaryl)
Ethyl Guthion® (azinphosethyl)	Sumithion®
Famophos® (famphur)	Temik® (aldacarb)
	TEPP
	Zectran®
	Zinophos®

12 October using ULV aircraft application. The dosage rate in one series was .0025 pound pyrethrins and .0125 pound piperonyl butoxide/acre which equates to a toxicant cost/ acre of 16 cents.

The results in this test indicated an average reduction at one hour of 67% and at two hours of 81%.

In a second series at levels of .005 pound pyrethrins and .025 pound piperonyl butoxide/acre, the percent reductions were 65% and 71% at one and two hours.

The target mosquito in both series was *Aedes nigromaculis* and the counts were based on the observations of two men in the field taking pre- and post-landing counts on their bodies.

This work indicates that further work with aircraft application of synergized pyrethrum should be undertaken.

McLaughlin Gormley King Company has recently prepared a bulletin on mosquitoes and *Chrysops* control with synergized pyrethrum. This bulletin entitled "Mosquito and Tabanid Adulticiding With Pyrethrum. 1972" gives in greater detail information I have touched upon in this talk.

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AERIAL APPLICATIONS OF MOSQUITO LARVICIDES FROM A TAIL BOOM

T. G. Raley

Consolidated Mosquito Abatement District

P. O. Box 278, Selma, California 93662

The idea of discharging spray materials from the tail of an aircraft is not new. In fact the first spraying for mosquito larvae control by plane was done from a boom under the horizontal elevators. As reported in the Proceedings of the Nineteenth Annual Meeting (1932) of the New Jersey Mosquito Extermination Association this revolutionary undertaking was quite successful. "The conclusions of the demonstration after field inspections on the following day were as follows:

1. Amount of oil sprayed was 180 gallons, costing $11.70.
2. Time of actual flying and spraying was 40 minutes, costing $40.00.
3. Area sprayed was eight acres.
4. An approximate kill of 98% of all larvae and pupae, one day after spraying.
5. Where grass grew more than four feet high, the oil mist reached the water surface and deposited a killing film.
6. Total cost of spraying including oil, airplane and flag bearers was estimated to be $52.50, or $6.53 per acre.
7. Approximate cost of hand spraying was estimated at $12.60 per acre (98% kill not considered possible with hand labor)."

Spraying with oil discharged from a boom on the tail of an aircraft was done at Consolidated Mosquito Abatement District late in the 1971 mosquito season. While this would indicate little if any progress in mosquito control during 40 years of effort some advances can be noted. After several demonstrations involving treatment of nearly 100 acres at nine different locations, conclusions were:

1. Amount of the oil mixture sprayed was 200 gallons, costing $125.00.
2. Time of actual flying and spraying was 100 minutes, costing $100.00.
3. Area sprayed was 100 acres.
4. An approximate kill of 99% of all larvae and pupae, one day after spraying.
5. Where grass grew as normal in an irrigated pasture that is a major mosquito source, the oil mist reached the water surface and deposited a killing film.
6. Total cost of spraying including oil, BAYTEX® and airplane (no flagman) was estimated to be $225.00, or $2.25 per acre.
7. Approximate cost of hand spraying was estimated at $4.75 per acre (99% kill not considered possible with hand labor).

With all the similarity of the trials in 1932 and 1971, progress in mosquito control operations have been quite positive. The difference in the amount of larvicide applied per acre, two gallons against 22 gallons, alone is of course the main difference. Improvements in aircraft have been more than noticeable, too. The plane used for applying the insecticide from the tail boom was also equipped with a separate wing boom spray system rigged to apply six ounces of insecticide per acre. The pilot could switch from one system to the other in flight.

ULV formulations of suitable insecticides have been applied by aircraft at Consolidated MAD for several years. This method still gives satisfactory results in most parts of the District but enough misses are occurring to demand another approach. Promising petroleum products offered one avenue to explore. Some even showed possibilities of giving good mosquito larvae control at reasonably low volumes per acre. A project was initiated to develop suitable methods to apply up to five gallons of oil per acre by aircraft. This brought the tail boom back into consideration.

Applying larvicides from aircraft through a tail boom had been tried earlier at Consolidated. These trials had been stimulated by a desire to get more spray material from the plane to the target area. Tests in the District and reports by other workers indicated only fractions of the toxicant discharged from wing booms were getting to the water surface. Some reports showed as little as 12%, others were more charitable and showed as high as 50% to 60%. ULV formulations discharged through suitable nozzles fixed to a tail boom did an excellent job of getting material to the target area. Unfortunately it placed the material in such a narrow swath the advantages of the ULV method were lost. At that time several of the approved insecticides were still doing a good job as area sprays so the tail boom study was tabled.

As the materials being used in the ULV and other spray methods gave poorer and poorer results attention was forced to the old standby, oil. New formulations showed promise at rates that were economically feasible as larvicides. Some were even safe enough to use in large volume on agricultural crops and related equipment and structures. Field spraying with ground units and laboratory tests indicated these gave reasonably good results on late instar larvae and pupae at from three to five gallons an acre. Getting this amount of material from the plane to the water surface was the challenge. Reports from other agencies conducting trials on aircraft applications of oil and first hand experience at Consolidated prompted a search of the storage shed for the tail boom.

The tail boom resurrected from the discards was approximately four feet long with suitable openings for four spray nozzles. After testing, two more openings were added to provide a total of six nozzles. The nozzles finally selected were, Type 4664 Diaphragm Tee Jet Brass with 1/8 inch NPT female inlet pipe connection. No orifice disc, strainer or other obstruction was used. The diaphragm was set to open at 25 pounds pressure. Treating a 35-foot swath at 90 miles an hour from an elevation of around 15 feet with the six nozzles gave an average application rate of two gallons of oil per acre.

For a base line of reference several test plots were treated with straight oil (Flit® MLO) at the two gallons per acre rate. Routine dipping after 24 hours showed fair results. Checks after 48 hours indicated little added benefit. The overall results, however, were good enough to indicate the method and material were coming quite close to giving satisfactory results. In that the operation was very clean, with little spray material getting on the plane either directly or in the fly back, it was decided to fortify the oil with a promising toxicant before going on to testing higher application rates. Baytex was still giving good results in most fields so it got the nod for the first trial of fortified Flit. The results were fantastic! Two gallons of Flit with enough Baytex to give 0.025 pounds per acre were applied in the first tests. The Baytex used was a seven pound Mosquitocide formulation supplied by Niagara Chemical.

In the early tests kill of all stages of larvae and pupae was so positive and so fast modifications of the spray mixture and flight pattern were tried. These led to the adoption of a more or less standard procedure of applying a mixture of 30 gallons of Flit with eight ounces of seven pound Baytex Mosquitocide at 1¾ gallons per acre in 50-foot swaths. The preferred plane operation was 90 miles an hour at a 15-foot elevation. Nozzle diaphragms were set to open at 25 pounds pressure.

It must be borne in mind that larviciding results in late September and early October can be quite different from the most active part of the season in August and early September. The trials with the Flit-Baytex combination will be resumed next spring. Laboratory tests showed it worked just as well on larvae from neighboring districts, as it did on local larvae. The borrowed larvae were taken from fields that had a history of almost total resistance to organic chemicals. If the synergizing action continues it will be quite welcome. Either way, studies will be expanded to test other oil-insecticide combinations and the application of higher rates of oil alone. The most acceptable spray could turn out to be Flit and a pyrethrum-type material.

Considering the use of large volumes of oil and oil fortified with a toxicant does raise the specter of very high costs per acre for larviciding. This fact of economics must be accepted, however, this in itself should not side track the search for a dependable larvicide that can be used year after year. In the Central Valley of California some larviciding will always be necessary if acceptable mosquito control is to be achieved. The objective at Consolidated is to find the larvicide and reduce the source area so that the total District budget is within reason. While we have only scratched the surface in the search for that perfect larvicide, source reduction is responding nicely to the Public Information Program. In the 1971 season a total of 43,250 acres were sprayed. This is down from 103,044 acres in the 1970 season, a decline just short of 60%. A determined effort will be made in 1972 to cut the acreage treatment record even more.

A benefit that could come from an oil-insecticide combination is the good possibility of it also serving as an adulticide. Adult mosquitoes do show up in and around sources. If this collection could be cleaned up periodically at the major aggravated sources dispersal might not stimulate so many service calls.

ADAPTATION OF JEEP POSTAL VAN DISPATCHER – 100 FOR MOSQUITO CONTROL

E. L. Geveshausen and Gardner C. McFarland

Southeast Mosquito Abatement District

9510 South Garfield Avenue, South Gate, California 90280

The Southeast Mosquito Abatement District (SMAD) lies wholly within Los Angeles County. The District comprises 255 square miles of the southeastern part of the County, plus the Los Angeles harbor area and Gardena, Carson, and Dominguez area of the County. In 1965, the District annexed all of the San Fernando Valley section of the City of Los Angeles, with an area of approximately 275 square miles. The population of the District is approximately 2,610,000 people. The area comprising the District is highly urbanized and has very little agriculture which is rapidly being converted to homes and industrial parks.

Control needs of the District are general throughout the District with thousands of miles of gutters, thousands of catch basins, and hundreds of miles of improved flood control channels. To adequately and economically control these areas, it has been necessary to make use of right-hand drive vehicles as they become available on the market. Use of right-hand drive vehicles has enabled the District to make use of one-man operations.

Service life of one of our vehicles is limited to about four years. We then replace them to enable the District to maintain the level of service that is demanded by citizens of the District. Bids are called for from the dealers in the District who are marketing this type of vehicle. However in 1971, California State Vehicle Smog regulations prohibited the sale of International and Jeep 4 cylinder engines.

At this time, the District was made aware of the availability of a Jeep Dispatcher 100 Model DJ-5B Post Office Van, made by American Motors Corporation. This is a right-hand drive vehicle with a six cylinder, 232 cubic inch 7 bearing engine, three-speed automatic transmission. The van-type body is built on a standard Jeep frame and the cargo bed has the same space as a standard Jeep DJ5. Sliding doors, right and left sides of the van body can be locked with the ignition key. The van body also has a swinging rear door with latch and lock, that is almost as wide as the cargo area. Options available with this vehicle are limited. The only options that were available at the time of purchase were right- or left-hand drive and paint. The vehicle otherwise was sold as manufactured.

The District has equipped the vehicles with a galvanized 55-gallon tank. The pump is powered by 24 volt, 7 amp, 1/8 hp motor and is integral. This pump and motor is a surplus aircraft fuel transfer pump. Motor and pump when used on a 12-volt system develop 40 pounds of pressure and meets the needs of the District in our larvicide oil spray program. Actuation of the pump unit is by a toggle switch mounted on the dashboard convenient to the operator. Each vehicle is also equipped with a three gallon stainless steel B & G hand spray can, one PCB granule spreader, inspection dipper, and sample bottles. All of the District vehicles are also equipped with two-way FM radios. operating on an exclusive frequency in the Local Government Radio Service.

Use of right-hand drive vehicles, in our one-man operational spray program has resulted in substantial savings in labor costs to the District. Trade-in value of our right-hand drive vehicle averages about $500.00 per vehicle. Savings to the District in labor costs with a one-man operation is approximately $1,500 per season over a two-man operation using left-hand or standard-drive vehicles.

OBSERVATIONS ON MALATHION THERMAL FOGGING IN A MIXED CONIFER FOREST AT LAKE TAHOE[1]

Richard Garcia[2], Kenneth H. Hansgen[3] and Fred C. Roberts[4]

Thermal fogging of 5% malathion and diesel mixture was the chief means of mosqutio control for the residents of South Lake Tahoe, California, during the years 1963 through 1966. Based on recommendations of a program review by the California State Department of Public Health, Bureau of Vector Control (Womeldorf 1966) more emphasis was placed upon larviciding during 1967 and 1968, however, malathion thermal fogging during this period was also applied routinely. Applications were administered on a weekly basis in all residential areas. Thermal fogging with

[1]We gratefully acknowledge Joe Sorrentino of the El Dorado County Service Area No. 3 for his technical assistance in this study.

[2]University of California, Division of Biological Control, 1050 San Pablo Avenue, Albany, California 94706.

[3]California State Department of Public Health, Bureau of Vector Control and Solid Waste Management, Office Building No. 9, 744 P Street, Sacramento, California 95814.

[4]Alameda County Mosquito Abatement District, 3024 East Seventh Street, Oakland, California 94601. Formerly of El Dorado County Service Area No. 3, P. O. Box 1234, South Lake Tahoe, California 95705.

the exception of several experimental applications was terminated after the 1969 mosquito season.

In the summer of 1968, the pine needle scale, *Phenacaspis pinifoliae* was found to be heavily infesting pine trees throughout much of the residential area of the City of South Lake Tahoe (Hunt 1968; Dahlsten et al. 1969). It was suspected that the natural enemies which normally controlled the pine needle scale had been severely reduced in numbers by the action of the malathion fog used for mosquito control (Dahlsten et al. 1969). Roberts (1971) summarized the extent of the scale outbreak and its relationship to the thermal fogging program. Since termination of the program the natural enemies have rebounded dramatically with a corresponding crash in the scale populations (Luck 1971, pers. comm.).

Few controlled studies have been made of the effectiveness of thermal fogging for mosquito control in the Sierra Nevada mountains. Fontaine and other workers from the Bureau of Vector Control in the late 1950's observed almost complete reductions of mountain *Aedes* based on body landing rate counts from one to two hours after fogging moderately large areas with vehicle mounted aerosol equipment applying DDT, malathion and lindane (Sherman 1972, pers. comm.; Smith 1972, pers. comm.). Lewallen (1964) reported 50% to 100% reductions of several species of mountain *Aedes* in small scale tests using fenthion, dichlorvos, Lethane 384® and malathion, basing his reduction percentages on body counts before and 30 minutes following treatment. Husbands and Soroker (unpublished data, 1968) observed inconclusive results with fenthion, Lethane and dibrom based on body counts before and up to 24 hours after treatment. Prine (unpublished data, 1969) observed very spotty results with a caged strain of malathion susceptible *Culex pipiens quinquefasciatus* exposed to the malathion thermal fog at South Lake Tahoe.

During 1970 and 1971, larviciding and source reduction techniques provided more effective control in the concentrated residential areas of South Lake Tahoe (Roberts 1971). However, because of economic constraints within the program, this level of control could not be provided to smaller residential populations living in scattered outlying areas. Residents of these areas have been requesting more effective mosquito control. Primarily because it is less expensive, and expedient, a malathion thermal fogging program is currently being reconsidered as a method to provide mosquito control to these outlying districts. The purpose of this study was to determine the effectiveness of this technique for mosquito control in small isolated forest residential districts.

MATERIALS AND METHODS.–The Spring Creek summer home tract in El Dorado National Forest, five miles west of the City of South Lake Tahoe was selected as the test area for treatment. An untreated control area was selected at Cathedral Meadows summer home tract on the west side of Fallen Leaf Lake, about one mile southeast of the test area. The Spring Creek tract was treated on the 4th and 17th of August, 1971 in the morning between 5 and 6 a.m. A Dyna-Fog 1200-B® insecticidal fog generator mounted on a vehicle was used for application of the malathion. The equipment was operated in the same manner in which the thermal fogging was done in the original program in the City of South Lake Tahoe. The vehicle was driven at a speed of between five and seven mph with an insecticidal output of 40 gallons (5% malathion in diesel oil) per hour. Treatment of the entire area required about 30 to 35 minutes.

Mosquito populations were sampled at both areas on the nights before and after treatments with modified CDC portable light traps baited with about two lbs of dry ice. Three traps were operated in each area in the same position each night. Traps were set out at dusk and picked up between 4 and 5 a.m.

During the second fogging application on the morning of August 17, aspirator collections at the same time intervals were made in both areas before, during and after the fogging treatments. Collections were made by teams of two workers each, one individual making the collections off the other's body, for 30 minute collecting periods during which the teams remained for ten minutes each at three separate sites approximately 50 to 100 feet apart. The team in the test area collected in an area entirely inundated by the malathion fog. Mosquitoes collected for each 30 minute period were placed in separate cloth bags and held 24 hours to determine mortality and then identified under a microscope in the laboratory.

Weather conditions during both tests were relatively similar. Ambient air temperature during the time of fogging was between 55° to 60°F. Air movement was almost calm with a slow drift from south to north. The fog coming from the generator first lifted to approximately 30 to 40 feet, and then settled to the ground creating a thick blanket which moved with the air flow to the north and down the drainage course of Spring Creek.

RESULTS AND DISCUSSION.–Mosquito species collected by CO_2 baited light traps are listed in order of dominance in Table 1. The snow *Aedes* represented over 50% of the collections during the first fogging test; however, by the second test the culicine mosquitoes were the most abundant.

Table 2 shows that mosquitoes were numerous in both the test and check areas during the first fogging treatment, but less numerous in both areas by the time the second fogging took place. This suggests that a natural decline in mosquito abundance had taken place. A comparison of light trap collections in the test versus the check areas reveals a high degree of variability among the light traps. No consistent or strong differences were evident to indicate satisfactory control due to fogging by light trap evaluation (Table 2).

Tables 3 and 4 show that mosquitoes, especially snow *Aedes*, were fairly numerous and troublesome in both areas before, during and up to four hours after the second fogging trial. Although culicine mosquitoes were present in the areas in comparable numbers to the snow *Aedes* as indicated by light trap collections (Table 2), they were not as readily attracted to human hosts during the morning collecting period. Of the total of 258 mosquitoes collected off human hosts, the culicines were represented by only 14 *Culiseta inornata* and 2 *Culiseta incidens.*

Figure 1 demonstrates the percentage reduction of snow *Aedes* occurring in the test area as compared to the check. This graph shows some relative depression in *Aedes* biting activity during and shortly after fogging, similar to, but not as great as those seen by Lewallen (1964) 30 minutes after fogging with a portable fog generator. By four hours after the fogging, however, there was almost as much activity as

Table 1.–Species of mosquitoes collected in order of dominance by CO_2 baited CDC light traps from Spring Creek and Cathedral Meadows near South Lake Tahoe during August 1971.

Aedes increpitus
Culiseta inornata
Aedes communis-hexodontus
Culex tarsalis
Culiseta incidens
Aedes fitchii
Aedes cinereus
Aedes sierrensis
Aedes vexans
Aedes cataphylla
Culiseta impatiens
Total mosquitoes – 4,591

would have been expected without the treatment.

Mosquitoes that were aspirated from human hosts during and after the treatment and held 24 hours had a much higher mortality than those collected in the untreated area. Out of 56 mosquitoes collected in the treated area, 43 died after the holding period as compared to one death from the untreated area. The highest mortality (97%) occurred in the group collected during the treatment and the lowest mortality (64%) four hours after treatment. These data suggest that from an operational standpoint the equipment and insecticide were performing satisfactorily.

In the evening following the morning treatment of August 4, four residents of the Spring Creek Tract were interviewed in regard to mosquito biting activity during the day. Their observations were mixed and contradictory as to the benefits of the control procedure.

The two sets of collection data obtained by the light trap and human landing counts, combined with the subjective observations of the investigators and residents at the test site, indicate that malathion thermal fogging was not very effective as a program to protect residents in small isolated mountain areas. Any apparent benefits that might be inferred from the data presented in this study should be qualified by the following observations:

1. Light trap comparisons between the treated and untreated areas did not demonstrate differences that indicated satisfactory control (Table 2).
2. Human landing collections conducted during the second fogging trial obtained results which suggested that the reduction of snow *Aedes* was transitory and returned to

Table 2.–Mosquitoes collected in CO_2 baited CDC light traps at Spring Creek and Cathedral Meadows near South Lake Tahoe during fogging tests conducted on August 4 and 17, 1971.

	Treated Area – Spring Creek Tract						Untreated Area – Cathedral Meadows					
		Pre-test	Post-test		Pre-test	Post-test		Pre-test	Post-test		Pre-treat	Post-treat
Species Collected	Site	4 Aug.	5 Aug.	6 Aug.	17 Aug.	18 Aug.	Site	4 Aug.	5 Aug.	6 Aug.	17 Aug.	18 Aug.
Snow *Aedes*	E1	84	30	8	3	8	C1	284	235	203	32	38
	E2	268	M*	M	12	9	C2	258	156	76	9	13
	E3	305	228	40	17	17	C3	28	80	44	2	6
Culex tarsalis	E1	3	16	5	0	2	C1	32	45	68	2	19
	E2	44	M	M	5	4	C2	12	8	20	2	3
	E3	68	32	40	2	4	C3	4	6	14	1	1
Culiseta inornata	E1	28	16	5	0	2	C1	66	215	96	52	42
	E2	328	M	M	4	11	C2	24	36	44	6	7
	E3	74	92	58	25	20	C3	40	46	54	3	1
Culiseta incidens	E1	0	0	0	0	0	C1	16	15	4	2	8
	E2	24	M	M	3	2	C2	21	12	8	3	2
	E3	4	4	3	3	3	C3	24	4	10	2	0

*M indicates trap malfunction, collection not counted.

Table 3.–Species of mosquitoes attracted to humans in order of dominance at Spring Creek and Cathedral Meadows near South Lake Tahoe on August 17, 1971.

Aedes increpitus – fitchii
Aedes communis – hexodontus
Culiseta inornata
Aedes sierrensis
Culiseta incidens
Total mosquitoes – 258

pre-treatment activity within a few hours after fogging (Figure 1).

3. Forest entomologists suggest that thermal fogging is disruptive to natural arthropod regulating mechanisms in forest ecosystems and may induce other pest problems (Dahlsten, et al., 1969).

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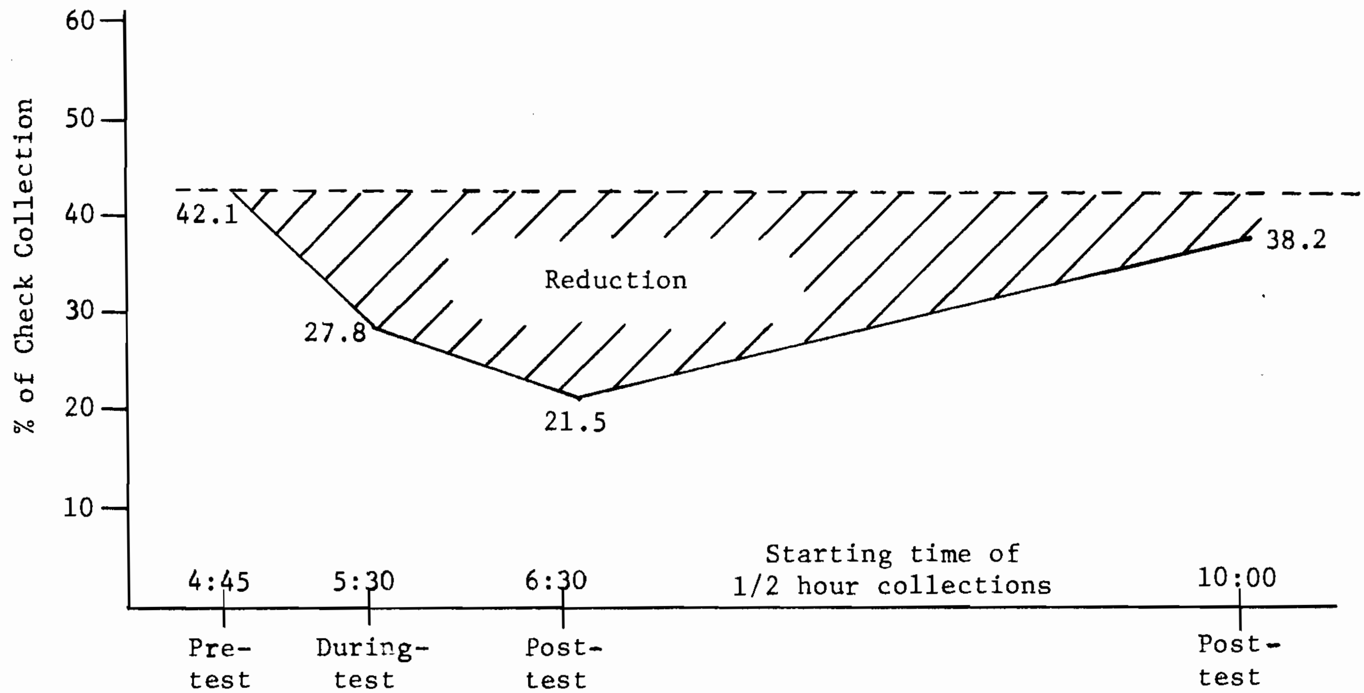

Fig. 1.–Aspirator collections of Snow *Aedes* females in the treated Spring Creek area shown as percent of collections in the untreated Cathedral Meadows area, South Lake Tahoe on August 17, 1971.

Table 4.–Total number of mosquitoes aspirated from human hosts at ½ hour intervals at Spring Creek and Cathedral Meadows near South Lake Tahoe.

Time of Sampling August 17, 1971		Treated Area	Untreated
Pre-treatment	4:45 AM to 5:15 AM	10	21
During-treatment	5:30 AM to 6:00 AM	23	56
Post-treatment	6:00 AM to 6:30 AM	19	80
Post-treatment	10:00 AM to 10:30 AM	14	35

SOLID ULTRA LOW VOLUME

William Hazeltine
Butte County Mosquito Abatement District
Route 2, Box 2040, Oroville, California 95965

In order to put solid ultra low volume (ULV) in perspective, it is instructive to consider the use of standard formulations. In an emulsion, an oil solution is added to water. For conventional ULV, you can leave out the water and disperse the oil droplets in air. In the case of dust, a concentrate is usually mixed with an inert carrier. For solid ULV, you just leave out the inert diluent dust, and disperse the finely ground concentrate. For a wettable powder, the solid particles are mixed with water to form a suspension. Without the water diluent, you have solid ULV.

The criteria of ULV particle sizes for larviciding are expected to be different from those used for adult control, and I limit my discussion here to adult control techniques. For larviciding, the particle size would probably need to be larger to get water fallout.

Adult mosquito control with ULV is really quite old. Thermal fog is close to ULV and has evolved to the modern smokeless aerosol generators which are extremely successful in mosquito control (Mount et al. 1970: Stains et al. 1969). Mount (1970) has recently reviewed the subject of optimum droplet size for adult mosquito control.

Use of solid ULV has been reported for experimental tests on cotton (Lincoln & Dean 1967) and corn (Greene 1970: Harrell et al. 1970). The use of solid ULV for adult mosquito control is the next step in a logical progression of an evolving technology.

The problems that go along with the benefits of liquid ULV include the following:

1. Droplet size needs to be controlled, depending on the target and the ideas of the operator. Getting the desired droplet sizes without a significant number of undesirable sizes, continues to be an area of research and experimentation.
2. Bioassay in the field to determine optimum size has been restricted because of the variation in droplet patterns produced with the available equipment.
3. Spotting of painted surfaces and deposit of oil residues on plants is a problem with oil solutions. In some cases, problems can arise from the solvent, but it may also occur if the insecticide is used without any other solvent diluent.
4. Generation of small particles usually requires a high energy source, and this is usually heavy and noisy.
5. Slight variations in operating conditions can cause large variations in the droplet size spectrum produced.
6. Suitable solvents for some compounds can be a limitation on the concentration of a chemical in solution. Baygon® is limited in solubility and low concentration solutions are all that can be obtained. Higher concentrations can be achieved by use of more exotic solvents, but these usually present more risk of surface damage.

Solid ULV appears to overcome some of the problems of liquid ULV in the following ways:

1. Particles are made in the formulation process, and an examination under a microscope will show the sizes that are present. It is also possible to blend batches for a broader range of particle sizes. At the 1 to 20 micron size, particles of solid should behave about like those from liquids as far as settling and drift are concerned.
2. Dry formulations should cause no problems on surfaces. There is also no concern on solvent evaporation because there is no solvent.
3. Because the energy to form the small particles is applied in manufacture, the only field energy required is that needed to meter the concentrate, and to disperse it in the moving air currents. There is no high energy, noisy or heavy equipment required. Contrary to the desire for psychological impact of control a few years ago, the present need seems to be for quiet, quick applications with as little disturbance as possible.
4. With already formed particles, there is no concern about flow capacity of equipment changing particle size. Accurate measuring is the only major constraint on equipment speed in application. If you want to drive faster, you simply increase the feed rate.
5. There appears to be less risk to humans and other mammals because of the way our respiratory system operates. Solids are less liable to be absorbed, and can be coughed up. Liquids tend to stick on the surfaces, and because they are in solution they would be expected to pass through membranes more rapidly.
6. Chemicals which are solids are a natural for the dry formulation. In addition fire hazard from solvent is not present and shipping weight is reduced.
7. By avoiding larger particle sizes, it might be possible to reduce residues on non-target plants. Telle (1970) has briefly considered the droplet size necessary to achieve impingement on beans and cereal plants. By using the same information, we could possibly restrict the particle sizes below those which would stick to plant surfaces, and thereby come closer to precision application without causing residues.

There are some problems with solid ULV which need to be considered. One of the most important is the commonly believed idea that dust drifts more than liquid, and drift is bad. Actually the reverse of this seems more correct. Thermal fog, cold fog and household aerosols all are successful only when there is drift. The common misunderstanding apparently arose because dust was visible and the fine droplets from liquid spray was not visible, and resulted in an idea that what you cannot see you do not worry about.

Precise application equipment is necessary to apply the required small amounts of solid concentrate. For example Baygon 70% WP applied at the rate of 1/100 pound AI per acre in a 500-foot swath would require about 25 pounds of concentrate per hour, and cover about 1,750 acres. Twenty-five pounds per hour converts to about five cubic inches per minute for the proper feed rate and this should be evenly dispersed over 440 feet of travel. It should be obvious that the equipment for application must be able to deliver the desired amount accurately.

Augers are not precise enough for metering and a system has been devised using a timing belt and a variable speed drive to get close to the desired accuracy. The system picks up the powder in the belt teeth and moves the dust to the air flow where the powder is blown off the belt and into the air stream. The heart of the system is a Zero-Max® variable, slow-speed drive device.

It seems appropriate that equipment suppliers will need to be involved so they can develop a suitable piece of equipment before development can proceed beyond the early test stages.

The pesticide manufacturer also must become actively involved along with the equipment supplier, in a team effort. Without a registered product, the machine is not worth much, and a product without the precision equipment to use it, is equally useless.

Registration will be a paramount problem, followed by the willingness of the manufacturer or formulator to make a product for this specific use. Most liquid ULV products have been developed from an already available product or something obtained at some point in the formulating process. The idea of a solid concentrate formulation for this use without dilution is unusual. Registration restrictions could kill the development of Solid ULV or delay it until its needs are imminent, such as a vector-borne epidemic. This, of course, does not allow the time necessary to develop a technology and a chance for the supplier to recover the development costs, through reasonable marketing. Last minute, all out efforts to develop a new technology usually are wasteful of resources and are a high risk, high cost approach to problem solving.

If solid ULV ever becomes an operational reality, it will be through a cooperative effort of equipment and chemical suppliers working together. It will also depend on non-abuse by agencies and individuals who need the technology but may be tempted to go operational before the necessary tests are made and registrations and clearances are issued.

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VERTICAL DRAINAGE FOR MOSQUITO ABATEMENT IN SMALL PROBLEM AREAS ASSOCIATED WITH IRRIGATED FIELDS: A PROGRESS REPORT

Leyburn F. Lewis, Darrell M. Christenson and William M. Rogoff

United States Department of Agriculture

Entomology Research Division, 5544 Air Terminal Drive, Fresno, California 93727

At the CMCA's 39th Annual Meeting in Oakland in 1971, we discussed the possibility of using vertical drainage as an adjunct to existing water management practices in irrigated fields in the Central Valley of California (Lewis and Christenson, 1971). We expressed the opinion that vertical drainage of surface water could be obtained in some areas in alluvial soils by boring holes into an underlying permeable layer and cited the limited evidence from which we had formed our opinion. It was and is our view that where such drainage can be obtained it should be a useful tool for mosquito control agencies which are faced with small problem areas in fields that are otherwise well-contoured and watered, in acreages where alternate cropping systems and good cultural practices are nonfeasible, and in a variety of other situations, such as grader ditches, where the seepage of irrigation water creates temporary mosquito habitats.

To explore further the feasibility of such drainage, we set up a study project at the Western Insects Affecting Man and Animals Laboratory in Fresno. Some of the results constitute the subject matter of this paper.

MATERIALS AND METHODS.—For the project we obtained a farm-type tractor with a skip loader from military surplus. Cooperators at Fresno State College restored the tractor to good condition and constructed a detachable, five-foot long auxiliary boom that attached to existing brackets on the loader bucket arms at the front end of the tractor. Then a hydraulic boring head was mounted on the auxiliary boom to drive our heavy duty six-foot-long augers, one 9-, one 6-, and one 4-inches in diameter along with an appropriate number of auger extensions. So the augers could penetrate hardpan, each was equipped with a special boring head. Two-way hydraulic cylinders were substituted for one-way cylinders on the loader, and a larger hydraulic pump and an additional tank for hydraulic fluid were mounted on the tractor. The assembled equipment is illustrated in Figure 1.

With the enumerated equipment we could bore holes to a maximum depth of about 13 feet. We filled all such holes with a ¾-inch aggregate topped off with about four inches of loam.

At the outset, the primary question was whether drainage could be obtained by boring holes with our equipment. Any question of optimum depth, auger diameter, or number of holes per acre was moot unless we could produce drainage.

Fig. 1.—Drilling equipment used to obtain vertical drainage, showing hydraulic boring head and 6-inch auger with extensions.

RESULTS AND DISCUSSION.—Our first series of holes were bored in problem areas in small pastures at Fresno State College. The College has many of these pastures, each complete with its own irrigation system, including return ditches for the tail water. These small pastures served well for the preliminary work because we needed experience and information of a general nature.

All problem areas investigated were underlain by a rock-like hardpan. Just to get through the hardpan, most holes had to be from five to nine feet deep. Also in places two layers of hardpan were present with the deeper of the two extending to about the nine-foot level. To penetrate the hardpan we had to place almost the full weight of the tractor's front end on the auger with the down thrust provided by the two-way hydraulic cylinders.

In addition, the heavy soils lying above the hardpan meant that any water that drained must flow directly into the opening of the drainage hole, that is, to be completely effective a hole had to be at the lowest point in the area to be drained, and the water had to have direct access to the hole over an unobstructed surface; on occasion, therefore shallow ditches were required. Otherwise, even small quantities of water would not dissipate laterally through the heavy soil within a short enough time to prevent mosquito emergence, and this slowness also limited the usefulness of the process in draining mudholes.

We also learned that in choosing the diameter of the auger an important practical consideration was the volume displaced by the auger. A nine-inch-diameter hole ten feet deep would require about 490 pounds of aggregate, a six-inch-diameter hole of the same depth would require about 220 pounds, and a four-inch-diameter hole would require about 95 pounds.

Although the problem areas in all the small pastures tested were generally broken up by return ditches, cross fencing, watering troughs, or feeders, all of which tended to limit the number of good experimental sites, we were encouraged by our findings. In areas where our holes were well-placed and the tail water return system worked, we were successful in draining off standing water within 24 to 72 hours after the flow of water had been shut off.

Our second series of holes was bored in a 40-acre alfalfa field with 30-foot-wide checks (strips with parallel earth dikes called border ridges) which sloped from north to south. This field also had return ditches for tail water. For irrigation purposes, the College had divided the field into three north-south sections each watered independently. However within each of the three sections, all checks were irrigated simultaneously so each received about the same volume of water over the same period of time. The holes were bored at the north end of the center section of the field where a roughly semicircular, mosquito-producing area extended from the boundary fence southward for a maximum distance of about 200 feet. All alfalfa in the mosquito-producing area had been drowned out and the vegetative cover consisted of water-tolerant herbaceous plants. Checks designated here as 1, 2, and 3 within this center section were alike in the extent of their individual mosquito-producing areas.

The first nine holes in the center section were bored in check 1. All were from seven to nine feet deep by nine inches in diameter, and all but one went through an underlying layer of hardpan; the one ended within a second layer of hardpan at the nine-foot level. When they were flooded, five of the holes drained off all immediately surrounding water within 24 hours, but the other four holes drained little or no water. However, a series of hastily made ditches leading to the five functional holes completed the drainage of check 2 within 72 hours; water stood for at least six days on companion checks.

Before check 2 was reflooded, four new holes, each a full nine feet deep, were bored as replacements for the nonfunctional holes. However, once again some ditching was required to obtain complete drainage within 72 hours. We then bored a second set of replacement holes, each of which penetrated into an underlying sandy layer at a depth of from 10 to 11 feet. As a result, after each subsequent flooding, all standing water was gone from check 2 within 24 hours; water stood on companion undrained checks for a minimum of six days.

When it became evident that vertical drainage could be obtained on check 2 with a nine-inch-diameter auger we bored 15 six-inch-diameter holes, each seven to eight feet deep, in check 1. All holes went through the hardpan, but none penetrated into a sandy layer. When this check was flooded, no visible drainage occurred, and water stood for at least six days. We then rebored a complete set of six-inch-diameter holes in check 1, all of which penetrated into an underlying sandy layer at a level of 10 to 11 feet. As a result, after each subsequent flooding, all standing water was gone from check 1 within 24 hours though water stood at least six days on companion, undrained checks.

After work was completed on check 1 we bored 13 holes in check 3 with a four-inch-diameter auger, all through hardpan into an underlying sandy layer at the ten- to 11-foot level. Because of the lateness of the season, check 3 was flooded only once before cultivation, and this one flooding occurred after the initial contouring had been somewhat disturbed by disking. However, the drainage rate in check 3 appeared comparable to that obtained in checks 1 and 2. Further confirmatory work with the four-inch-diameter auger is needed.

We also bored other series of holes during the summer including one series designed to provide us with an estimate of the minimum number of holes required per acre for adequate drainage in problem areas at the College. One yielded information that contradicted the results presented, but too few observations were made to produce definitive information.

Despite the obviously limited scope of the work described, it was performed in fields that were actively cultivated. Therefore, since we in no way interfered with or modified the watering, harvesting, or grazing schedules or other activities in these fields, we believe we have demonstrated that vertical drainage of surface water can be obtained in small mosquito-producing areas in alluvial soils by preparing drainage holes that penetrate into an underlying permeable layer. We also demonstrated that more than one diameter of auger may be used for the purpose, and that the mere penetration of a hardpan or other restrictive layer will not assure drainage.

Since this is a progress report, some statement of future objectives seems in order. Our immediate objectives are to test our procedures and equipment in other problem areas. In areas where vertical drainage will work, we need to investigate the interrelationships between hole depth and diameter and the acre-inches of water that a given number of holes per acre will drain in a given unit of time. Also, in all areas, we need an estimate of the functional life of drainage holes.

Our long-range objective is to work with other agencies that are more qualified and have more resources to determine the full usefulness of the concept of vertical drainage. Mosquito control is our objective and the only goal towards which we contemplate working, but if ponded surface water can be moved downward through drainage holes, it should be possible to use a system of drainage tiles to move surplus subsurface water downward through the same holes. Such increased subsurface drainage would provide both improved land use and mosquito abatement. Moreover, it seems to us that where better land use can be obtained, farmers themselves (as contrasted to owners of small acreages) will install and maintain vertical drainage systems in what are now purely nuisance spots.

On the basis of our encouraging experiences, we believe that vertical drainage holes drilled in problem areas and filled with a coarse aggregate can be a useful adjunct to mosquito control in areas where other water management procedures are impractical.

Acknowledgements

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STUDIES ON THE ECOLOGY OF THE TREEHOLE MOSQUITO *AEDES SIERRENSIS* (LUDLOW)

Richard Garcia and Gordon Ponting
University of California
Division of Biological Control, 1050 San Pablo Avenue, Albany, California 94706

The treehole mosquito, *Aedes sierrensis*, is an important pest in many of the urban and suburban areas of California. Rot holes in trees form the primary breeding sites, however, in mountain forest areas where logging operations have occurred in the past, tree stumps also form ideal breeding sites (Jenkins and Carpenter 1946; Mortenson 1969; and others).

Over the last year and a half we have been monitoring a population of *A. sierrensis* in a hardwood forest of Marin County: a cooperative project between the University of California and the Marin County Mosquito Abatement District. The overall goal of the project is to study this mosquito in a typical natural habitat from an ecological point of view, in order to gather information on the natural mortality factors which regulate its populations. It is anticipated that an understanding of these mortality factors may allow us to utilize them in a specific manner to control this mosquito. In a broader sense we also hope that some of the microbial agents which have been isolated from this mosquito will be adaptable to other mosquito species in different aquatic habitats. Sanders (1972) describes some of the agents which have been isolated from *A. sierrensis* and the role of insect pathology in this program.

The data in this paper are presented from a general view since much of the information acquired over the last year and one-half requires further analysis.

The study site consists of a tree covered ridge area comprising several acres with the dominant tree being coastal live oak. Oaks represent about 85% of the trees in the area. The next most abundant tree is California laurel, the remaining few trees are madrone and buckeye. The trees are densest on the northeast facing slope and form a more or less complete canopy. The oak and laurel are more evenly distributed on this side while the opposite side of the ridge is more open and composed mainly of oak. There are about 1700 trees in the study site in which 220 treeholes have been located and are being monitored.

The emergence cage is one technique which we have employed routinely to monitor these mosquito populations. The cages are constructed of fine cotton mesh (60 mesh/inch) in the form of a sleeve with a drawstring inserted at one end. The open end is fitted over the treehole opening and attached with 9/16 inch aluminum tacks. Emergence cages are attached during the winter months when there is no adult activity. Eggs laid during the summer hatch after the first period of continuous heavy rains. For the past two seasons the initial hatch has occurred during the last two weeks in November. Development is quite rapid at first with 4th instar larvae present in the treeholes by late December. There is, however, a wide variation of instars in the treeholes. All instars (1st thru 4th) can be found in treeholes during late December. This staggered development is apparently due to residual hatches from eggs laid in previous summers. However, it appears not to be entirely related to alternating wetting and drying periods because the majority of treeholes remained full of water during this entire time. The variability in hatching of *A. sierrensis* eggs in relationship to the amount of dissolved oxygen as reported by Judsen et al. (1966) more appropriately explains the wide distribution of instars early in the season. In addition, the larval development period can be exceedingly long as reported by Freeborn (1962) and Reeves (1941). Larvae were observed in one treehole for as long as nine months during this study.

Laboratory studies indicate that the length or change in length of the photoperiod influences larval development. In one study larvae were removed from four treeholes in early December and brought back to the laboratory. The larvae ranging from 1st to 3rd instars were divided into equal numbers of 50 larvae each and placed into similar containers with equal volumes of water. One series of larvae from the four treeholes was exposed to a short continuous light period of 9 hours and 30 minutes while the other was exposed to a light period increased by 15 minutes a day from 12 hours to 15 hours and 15 minutes. Wheast®[1] as a food source was added in equal amounts to each container throughout the experiment, and distilled water was added periodically to maintain the volume. Temperatures were kept at a con-

[1] Dried, inactive *Saccharomyces fragilis* yeast and whey proteins.

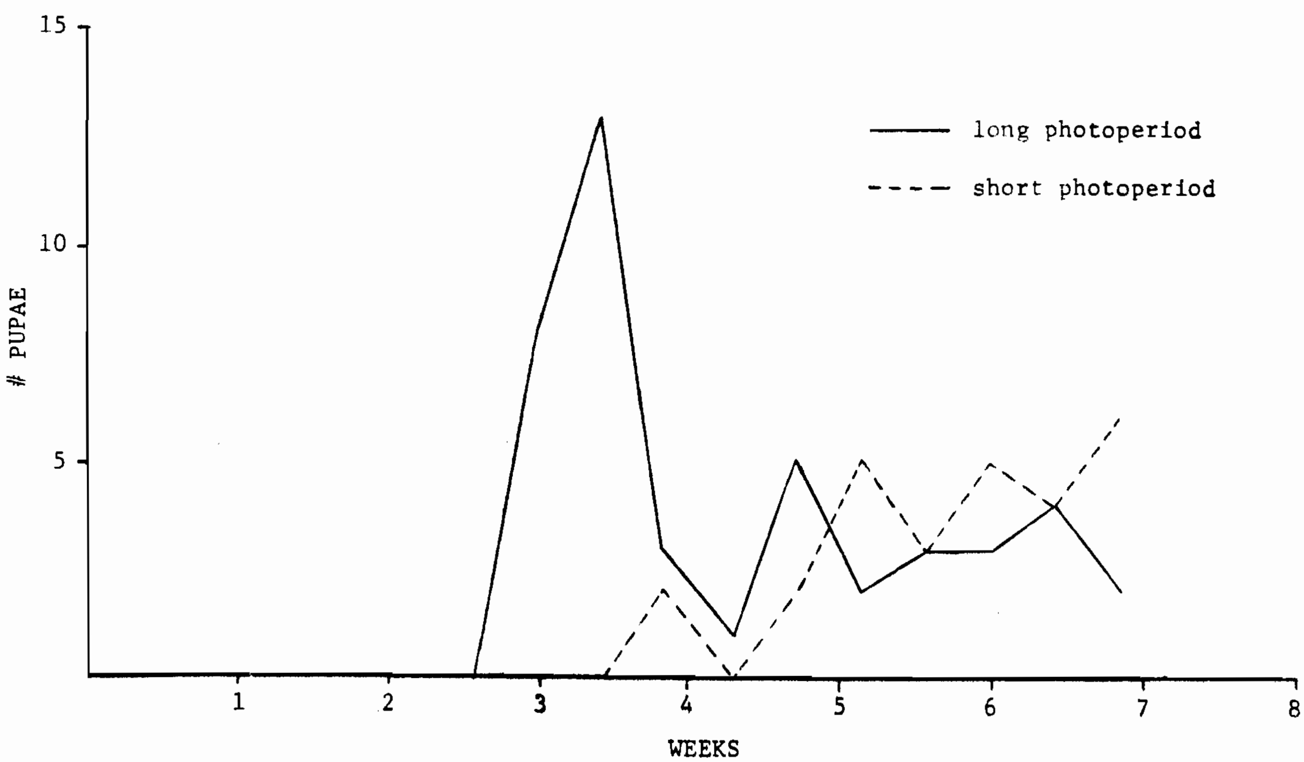

Fig. 1.–Immature *Aedes sierrensis* development to pupation under different photoperiod regimes. (Short photoperiod: 9 hrs. 30 min. continuous light out of every 24 hr. period. Long photoperiod: increased 15 min. per day from 12.0 hrs. to 15 hrs. 15 min. continuous light out of every 24 hr. period; then maintained at 15 hrs. 15 min.)

stant 68 ± 2° F. Development under both light regimes progressed at about the same rate for the first two weeks until almost all individuals in both tests were either 3rd or 4th instar. By the midpoint of the 3rd week the larvae under long light regime began to pupate (Fig. 1). Pupation did not occur in the short light regime until one week later and then it was much more gradual. These tests were complicated by a latent fungus infection which killed more of the larvae under the long light. Although the long light period appears to have influenced the rate of larval development, it is not clear whether this was a direct or indirect relationship. Microbial growth was noted to be heavier in containers under the long light suggesting the possibility that nutritional factors may have influenced the larval development.

A direct natural mortality factor which relates to prolonged larval development was seen in the fact that certain holes became dry before adult emergence could take place. Total mortality was noted in some of the small shallower treeholes during a drought period which lasted from approximately mid-January to mid-March. During this period a total of only 0.2 inches of precipitation was recorded. It appears that a thorough drying of the treeholes is necessary to produce total mortality. Treeholes which appeared to be dry but contained some moisture produced viable larvae and pupae within a few minutes after distilled water was added to the holes. This species appears well adapted to survive long periods in the absence of free water. In the laboratory this was confirmed by placing larvae and pupae over wet cotton in sealed plastic 50 ml containers. The containers were fitted inside with a small aluminum platform which supported a cotton organdy disc about 1½ inch above the cotton. Excess water was removed from the mosquitoes with absorbent tissue before placing them on the organdy base. Table 1 shows the survival times at two different temperatures. Pupae were the most resistant and some individuals were able to emerge to adults under these conditions. To test viability after the exposure period, individuals were placed in water. The stress of prolonged periods out of water was exemplified by the behavior of the larvae and pupae immediately after immersion. They generally remained quiescent for a short period as though absorbing water, and then required several minutes or more before their movements appeared normal. Development generally continued normally thereafter.

In summary, it is anticipated that the data presented in this paper, in conjunction with continued investigations on other natural mortality factors, will be useful in planning a program for an integrated approach to the control of this species.

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Table 1.–Survival of immature *Aedes sierrensis* over water soaked cotton.

	PUPAE (42°F)		4th Instar LARVAE (42°F)		4th Instar LARVAE (68°F)	
DAYS	SURVIVAL	(NO. TESTED)	SURVIVAL	(NO. TESTED)	SURVIVAL	(NO. TESTED)
0-5	100%		84%	(38)	20%	(40)
6-10	95%	(19)	62%	(34)	8%	(40)
11-15	75%	(12)	29%	(38)		
27	62%	(8)				

MICROBIAL MORTALITY FACTORS IN *AEDES SIERRENSIS* POPULATIONS

R. D. Sanders
University of California
Division of Entomology, 201 Wellman Hall, Berkeley, California 94720

The Insect Pathology Laboratory at Berkeley is conducting a survey of the diseases of *Aedes sierrensis* and attempting to assess their relative importance as population regulating factors. This survey, and a concomitant ecological study in the same area by the Division of Biological Control at Berkeley, aim at developing an integrated control program for *A. sierrensis*. This paper summarizes the disease-causing organisms recovered during the first year of sampling.

Eighteen treeholes in the study area near Novato, Marin County, were used for this preliminary study. Samples of treehole water containing mosquito larvae and pupae were aspirated from the treeholes and transported to the laboratory for analysis. Mosquitoes were examined under the dissecting microscope and the pathogens isolated and placed on culture media or preserved for future examination. Some infected mosquitoes were fixed, sectioned and stained for microscopic examination to determine the pathologic effects of the organism on the host.

Four of the 18 treeholes contained from 26-91% of the mosquitoes infected with the fungus, *Beauveria tenella* (Table 1). This fungus invades the siphon and saddle region and may later become established at the intersegmental membranes, most notably in the neck region (Fig. 1). The siphon may become packed with fungal hyphae, thus suffocating the larva, and the anal papillae may eventually drop off. The mosquito dies when the mycelia penetrate through the cuticle and into the hypodermis and other tissues. Light *B. tenella* infections occurring on the external surface may be cast off when the mosquito moults.

Tetrahymena sp., a ciliated protozoan, and a mermithid nematode were present in mosquitoes from one of the treeholes (Figs. 2, 3 and 4). Of the 320 mosquitoes examined from this treehole, 77 were parasitized by *Tetrahymena* sp., 32 by mermithid and 43 by both pathogens (Table 1). Once the body cavity is invaded by either or both of these two pathogens, they appear to grow and develop unchecked on the host's food reserves which eventually results in death of the mosquito. In addition, 83 mosquitoes in this treehole were infected with *B. tenella*. The total mortality attributable to the three diseases amounted to 73% in this treehole. The specific interactions between these disease and their hosts are not clearly understood; nor do we know their effects on the early larval instars since samples were taken too late in the season to obtain young larvae.

These preliminary findings indicate that *B. tenella* has potential as a practical control agent. Laboratory and field tests are in progress to assess its effectiveness. *B. tenella* appears to be present to some extent in most, if not all, treeholes, while *Tetrahymena* sp. was found only occasionally in several other treeholes and the mermithid was found only in the single treehole. It is not known why certain treeholes contain populations of mosquitoes with epizootic levels of disease while others have considerably less infected individuals.

Clearly, these groups of pathogens have been demonstrated to cause mortality in mosquitoes under laboratory and field conditions (Corliss, 1960; Laird, 1971; Petersen, et al., 1968). Studies in progress are attempting to quantify some environmental parameters within a treehole (pH, oxidation-reduction potential, surface area). It is possible that various combinations of these factors lend to a high incidence of disease. Thus, manipulating the treehole conditions or simply augmenting existing pathogens might lead to decline in mosquito populations. We are also investigating resistant stages of pathogens during the summer dry period when hosts are usually absent. Suitable conditions during these periods may allow the pathogens to survive during the summer and to have a greater impact when the hosts become abundant.

A. sierrensis can be a severe nuisance species during the Spring as it bites humans where natural hosts are not readily available. It frequently breeds in treeholes in back yards and wooded areas near homes. This species is not easily controlled with standard techniques as the larval habitats must be treated individually and are often inaccessible. Until recently, DDT was used to control larvae but lately Dursban has proven useful although it is less persistent. DDT has been retained for mosquito control for 1972 in California for use against *A. sierrensis*, although few mosquito abatement districts still use this chemical. Fogging may occasionally be used against adults.

For the following reasons, namely the difficulty of control, frequent contact with man in certain areas, and the continued use of a chemical that is being phased out in California, an ecologically sound and effective alternative to present techniques would be of great advantage. Pathogenic microbes may offer some unique advantages in that they are generally not ecologically disruptive, non-toxic and take advantage of certain weaknesses in the life cycle of their hosts. At the same time they possess residual qualities since they are already found in the mosquito's environment. The use

Table 1.—*Aedes sierrensis* field collections, Novato, Marin County, California.[a]

Treehole	Mosquitoes examined	Disease organism	Percent diseased
1	235	*B. tenella*	91
2	43	*B. tenella*	51
3	15	*B. tenella*	33
4	320	*B. tenella* *Tetrahymena* sp. mermithid both T. and M.	73

[a]18 treeholes – 4 with disease epizootics.

Fig. 1.–*Beauveria tenella* invading the anal saddle of *Aedes sierrensis.*

Fig. 3.–Mermithid nematode in the head capsule of *Aedes sierrensis.*

Fig. 2.–*Tetrahymena* sp. infecting the anal papillae of *Aedes sierrensis.*

Fig. 4.–Mermithid nematode emerging from the anus of an *Aedes sierrensis* larva.

of microorganisms combined with source reduction (filling treeholes with sand, or proper pruning techniques) may prove to be of greater value in the future. With studies under way we hope to take advantage of these and other factors to develop a sound and effective program to manage *A. sierrensis* populations.

Preliminary laboratory tests indicate that *B. tenella* may have potential in controlling other mosquito species. Larvae of *Culex pipiens*, *Aedes aegypti*, *Aedes dorsalis* and *Culiseta* sp. are susceptible to the disease when placed with spore concentrations of from 10^4 to 10^6 spores per ml. Field tests will be under way shortly to assess the ability of *B. tenella* to control several important species of California mosquitoes. In addition, this fungus can be easily and inexpensively produced.

It is hoped that with the information obtained from developing a population management program for *A. sierrensis* that similar approaches may be developed for other mosquitoes in California.

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THE USE OF OVITRAPS TO EVALUATE *AEDES SIERRENSIS* (LUDLOW) POPULATIONS

Earl W. Mortenson[1], George L. Rotramel[1] and Jerry E. Prine[2]

ABSTRACT

The western treehole mosquito, *Aedes sierrensis* (Ludlow) is not readily attracted to American model light trap or the CDC portable light trap baited with CO_2. Development and application of an artificial oviposition trap to attract oviposition females of *Aedes aegypti* as a method to evaluate adult female activity by the presence of eggs of this species, suggested that this technique might be useful to measure *A. sierrensis* activity.

The ovitrap consists of a wide-mouth pint jar painted black, filled with 200 ml of water with a fiberboard paddle inserted in a vertical position against the side of the jar that serves as a substrate for oviposition. The jar is attached to a lower limb or tree trunk about five feet from the ground.

In 1970 and 1971, 25 of these ovitraps were placed in two wooded areas, near Navato, Marin County, California, and Lafayette, Contra Costa County, California, from May through September. Results of the study indicated that *A. sierrensis* females entered the jars and oviposited on the fiberboard paddles. The ovitraps were first positive for eggs during the first and second weeks of May, respectively. In 1970 the highest number of eggs recovered from a single trap for a week was 495 the last week of May. The greatest number in 1971 for a single trap, 460, occurred the first week in June. In terms of percent ovitraps positive, two peaks of activity occurred, the first week of June and the second week of July in 1970. In 1971 the first peak of oviposition activity was in the third week of May and the last week in June followed by a third delayed increase the second week of September.

This study suggests that the use of artificial ovitraps to measure female *A. sierrensis* activity would be practical in organized mosquito control programs to evaluate effectiveness of chemical and physical control measures.

[1]California State Department of Public Health, Bureau of Vector Control and Solid Waste Management, 2151 Berkeley Way, Berkeley, California 94704.

[2]Lake County Mosquito Abatement District, 410 Esplanade, Lakeport, California 95453.

RESIDUAL ACTIVITY OF VARIOUS INSECTICIDES IN TREEHOLES

Melvin Oldham[1], Ernest E. Lusk[2] and Don J. Womeldorf[3]

Treehole mosquitoes, *Aedes sierrensis*, have been and will continue to be a major seasonal problem for many MADs over a good part of California. Each locality will vary somewhat in tree species and terrain but the basic problem remains the same –– finding and treating the trees which have cavities holding water and producing mosquitoes.

Much of the territory in Shasta and Tehama counties consists of rolling hills covered with native deciduous oaks, generally *Quercus douglasii* with occasional patches of live oak, *Quercus wizlizenii.* Over the past 50 to 100 years these trees have been harvested for wood fuel to use in steam boats on the Sacramento River and for cooking and heating in homes. This has resulted in the development of more *A. sierrensis* sources than would naturally occur. The current stands of these trees are at least second or third growth, sprouting from the cut off trunks and stumps of the previous stands. Each stump provides a potential treehole until it rots away enough to be self draining or heals completely over. More recently urban expansion has moved residential areas adjacent to and into the wooded areas and subsequent "aesthetic" pruning of the trees has produced more problems.

Some of the more favorably located holes are filled with the first rains in late October and November and nearly all that will hold water are filled by January. Barring an exceptionally dry period, most that become filled by January will hold water for the rest of winter and into spring.

First stage larvae can be found in the fall shortly after filling and if the hole remains wet these will rapidly grow to fourth instar and remain so through winter. Pupae appear about February and from February through March with the changing water levels from spring rains, first instar through pupae can often be found in the same treehole.

The adult flight of *A. sierrensis* occurs in Shasta and Tehama counties during late March and April, usually lasting four to six weeks. Late rains will extend the time by refilling the holes and early dry weather considerably reduces the problem.

A number of control methods have been tried in other districts including filling with sand, concrete, dirt, and insecticide applications. The filling method has been found to be time consuming, expensive and of questionable effectiveness because the holes continue to decay around and under the filling resulting in the resumption of breeding in a short time. Most effort, therefore, has been in treatment with insecticides (Brannan, 1964). Both wettable powder and emulsifiable DDT have been used in Kern, Alameda, and Butte districts. Butte MAD reported a minimum of three years control using DDT, with no reinfestation after eight years in some olive orchards (Portman and Hall, 1961). The Contra Costa MAD has also used phenothiazine successfully as a residual larvicide for *A. sierrensis* (Brawley, 1970).

During the winter of 1966-67 in the Tehama County MAD the first attempts at *A. sierrensis* control were made in a few selected locations near a residential area and a school in Red Bluff by filling with dirt all holes that could be found. There was a noted decrease in the numbers of adults in the immediate area during the following emergence period so it was decided to expand the control area. The next winter additional areas were treated by filling, but it was observed that some of the previously filled holes had settled, washed out or had been dug out by squirrels and were again producing mosquitoes, so the treatment was switched to insecticide.

Emulsifiable dieldrin or a DDT-toxaphene combination used straight or cut 50% with diesel oil was applied by one quart plastic trigger spray bottles in additional areas treated. The amount applied was determined by the operator's estimate of the volume of water and varied from one to several squirts of the trigger spray per tree. Although very time consuming to search the wooded areas for treeholes, the efforts in most cases seemed worthwhile. To date approximately 1200 to 1500 acres in the vicinity of Red Bluff have received this treatment.

In March 1970 the authors decided to test the longevity of some insecticides other than chlorinated hydrocarbons as residual larvicides for control of *A. sierrensis.* The four formulations selected were those available in the insecticide inventory of the Tehama MAD – Dursban® 4E, fenthion (MAD special mosquitocide), ABATE® 4E and Baygon® 70% W.P.

Ten trees (*Q. douglasii*) with holes infested with larvae of *A. sierrensis* were selected for each of the chemicals. The forty trees thus chosen were marked with red paint for easy relocation.

The volume of water in each hole was measured by siphoning the contents into a three liter graduated plastic pitcher. For those holes with volumes greater than three liters a five gallon plastic lined water can was used as a reservoir into which the pitcher was emptied. Volumes ranged from 200 ml to 20225 ml. After each measurement the water was immediately returned to the hole and the calculated amount of insecticide necessary to achieve a concentration of 1000 ppm was added and thoroughly mixed by stirring. Treatment dates were: Abate – March 16, 1970; Dursban – March 17, 1970; fenthion – March 23, 1970; and Baygon – March 27, 1970.

Approximately nine months later on December 9, 1970 all the treated tree holes and a series of check trees in each plot were examined for the presence of *A. sierrensis* larvae. No larvae were found in any of the treated holes while the check trees contained larvae up to the third instar.

Two treeholes from each of the four insecticide treatment plots were selected for bioassay tests to determine the level of residual activity. Approximately 100 ml of water

[1]Tehama Mosquito Abatement District, 429 Ash Street, Red Bluff, California 96080.

[2]California State Department of Public Health, Bureau of Vector Control and Solid Waste Management, 2135 Akard Avenue, Redding, California 96001.

[3]California State Department of Public Health, Bureau of Vector Control and Solid Waste Management, Office Building No. 9, 744 P Street, Sacramento, California 95814.

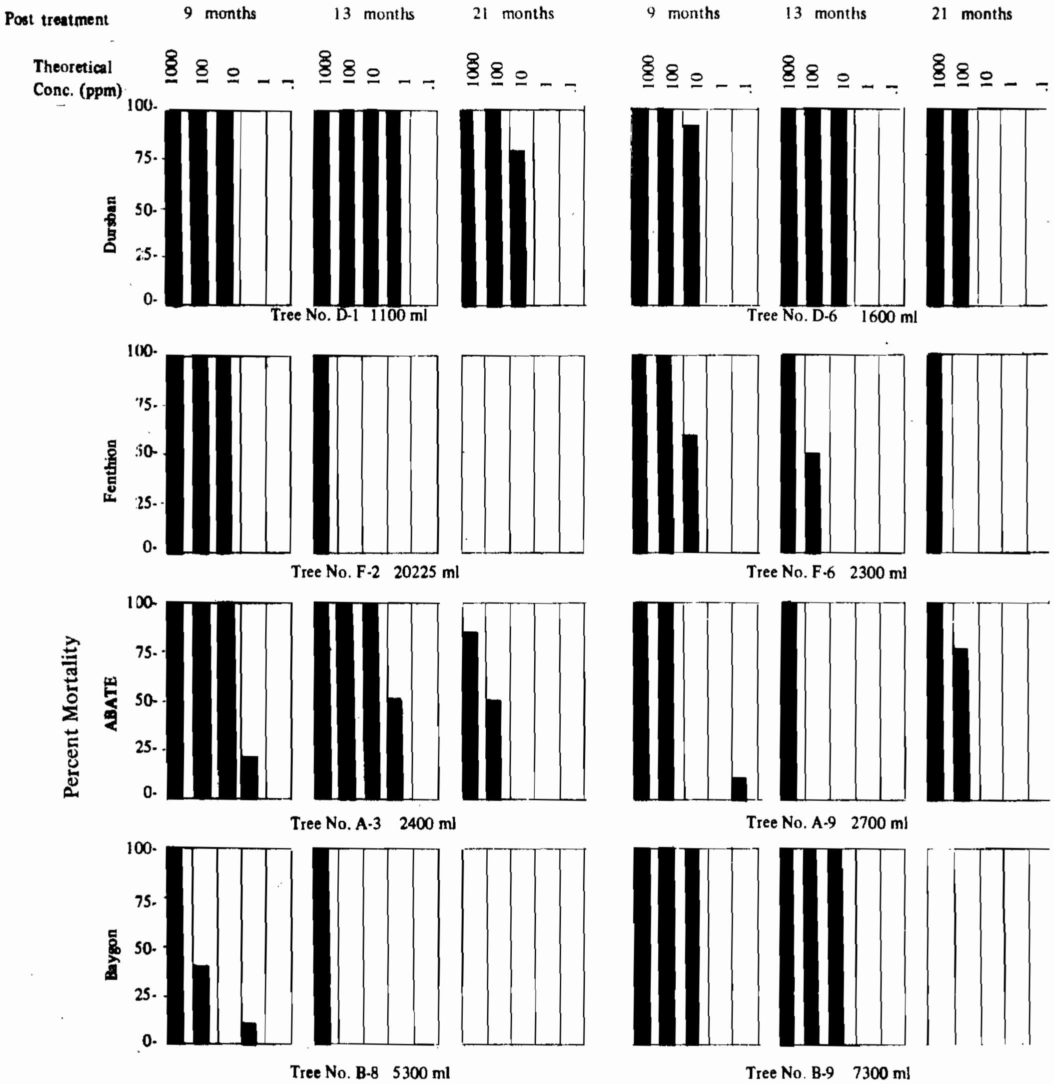

Fig. 1.–Residual activity of various insecticides in treeholes.

were withdrawn from each of the two trees selected in each plot. This water was placed in No. 143 Dixie cups with caps and returned to the Tehama MAD laboratory where a series of ten-fold serial dilutions were prepared from each sample with aged tap water. The resulting dilutions were then 1/10, 1/100, 1/1000, and 1/10,000 of the concentration remaining in the treehole. Similar dilutions were also prepared from a 100 ml sample of water taken from an untreated treehole. Ten pre-counted fourth instar larvae from the *Culex pipiens quinquefasciatus* colony maintained in the Sacramento office of the Bureau of Vector Control & Solid Waste Management were introduced into each cup by pouring them onto a nylon net square and quickly rinsing them into the test sample. A separate nylon square was used for each cup.

Mortality was evaluated at 24 hours. Figure 1 shows the results of this test and two subsequent bioassays at 13 months and 21 months after treatment.

Dursban was the most effective material giving in one tree tested 100 percent mortality to the *C. p. quinquifasciatus*

Table 1.–Concentrations of insecticide in treehole water as determined by bioassay, 12-12-71, Tehama County Mosquito Abatement District. Amounts adjusted for dilution factor in parenthesis behind amount measured in diluted sample.

Material	Tree No.	1000	100	10	1	0.1
Dursban®	1	.31	.057 (.57)	.0016 (.16)	0	0
Dursban®	6	.09	.02 (.2)	0	0	0
Dursban®	7	.31	.011 (.11)	.0023 (.23)	0	0
ABATE®	9	.0028	.0013 (.013)	0	0	0
ABATE®	3	.0015	.001 (.01)	0	0	0
fenthion	6	.0021	0	0	0	0
fenthion	9	.002	0	0	0	0
fenthion	10	.0065	0	0	0	0

larvae after 21 months at a one-hundred-fold dilution of the concentration remaining in the treehole. A test in a second tree produced 100 percent mortality at ten-fold dilutions and 77 percent in one-hundred-fold dilutions 21 months after application. Twenty-one months after treatment Abate and fenthion both gave 100 percent mortality in the undiluted concentrations in one test and 86 percent and 50 percent, respectively, in a second test. Baygon produced 100 percent mortality in the bioassays at the undiluted concentration after 13 months but failed to kill any of the *C. p. quinquefasciatus* larvae after 21 months.

A time-knockdown bioassay to determine the actual concentration of Dursban, Abate, and fenthion in the water in the test treeholes after 21 months was performed by Don Womeldorf using the method described by Gillies, Womeldorf, and Walsh (1968). Known concentrations of fenthion and Dursban were run for comparison. Abate concentrations were estimated against the Dursban knowns, since the two materials act similarly. Results of this test are shown in Table 1.

Limited reinfestation of treated trees after 21 months has occurred in the Abate, Baygon, and fenthion plots but not in the Dursban treated trees. As of January 27, 1972, there had been insufficient precipitation in the area to flood all the test holes. The percentage of holes currently flooded which were found positive for *A. sierrensis* was: Abate 10%, Baygon 50%, fenthion 33 1/3%. The final reinfestation percentages will probably be somewhat lower.

At this point our results indicate that of the four materials tested Dursban is the only one offering the potential of long lasting residual activity. DDT has recently been authorized for use as an insecticide for treehole mosquitoes at a rate not to exceed two grams of actual DDT per treehole. We plan to continue the observations and will add DDT, phenothiazine and possibly sodium chloride to the series of materials tested.

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SEASONAL OCCURRENCE OF AUTOGENY IN *CULEX TARSALIS* IN BUTTE AND GLENN COUNTIES[1]

Richard D. Spadoni and Robert L. Nelson

University of California

Arbovirus Field Station, 35--c Nimshew Stage, Chico, California 95926

ABSTRACT

Seasonal patterns of autogeny were observed in populations of *Culex tarsalis* in Butte and Glenn counties, California, from the fall of 1969 through that of 1971. Autogeny rates were determined in females that emerged from pupae collected from breeding sites, and in overwintering females collected as adults from shelters.

Autogeny rates from pupal collections followed similar trends in 1970 and 1971. Mean autogeny rates increased from less than 20% in March and April to more than 85% in August, and then decreased to less than 20% in October and November. Less then 1% of more than 1300 overwintering females showed evidence of autogeny after being held in the laboratory for ten days after collection.

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NIGHTLY PATTERNS OF BITING ACTIVITY AND PAROUS RATES OF SOME CALIFORNIA MOSQUITO SPECIES[1]

Robert L. Nelson and Richard D. Spadoni
University of California
Arbovirus Field Station, 35–c Nimshew Stage, Chico, California 95926

Seasonal patterns of mosquito infection with arboviruses are routinely determined by the systematic collection and testing of mosquitoes for these viruses. However, it also is important to know when in a 24-hour day, the mosquitoes are most likely to acquire and transmit these viruses. Although much is known about the feeding behavior of various species, detailed information on patterns of biting activity is unavailable for many species. Moreover, except in very few cases, it is not known if there are significant differences in parous rates in females that bite at different times of the day or night. Presumably virus transmission is limited almost exclusively to times when parous females are biting.

The present studies were made to establish the patterns of biting activity of several mosquito species, and to determine parous rates in biting females collected in different periods of the night. It was felt that the information obtained so far might be of interest, although more data are needed in many cases.

MATERIALS AND METHODS.–All observations were made on the Llano Seco Ranch about ten miles southwest of Chico and three miles east of the Sacramento River. A collecting station was established in a grassy clearing within a mature stand of valley oak (*Quercus lobata*). Biting collections always were made in the same way and by the same person (R.D.S.). Beginning at the hour of 1700 or 1730 (Pacific Standard Time) and continuing until 0700, attracted mosquitoes were collected by aspirator with the aid of a flashlight with the lens covered with red cellophane. The collector was seated with his legs exposed from the ankles to just above the knees, but mosquitoes were collected as they landed on any clothed or unclothed part of the body. Mosquitoes taken in each ½ hour period were held in separate one-pint cartons until later identified and dissected in the laboratory.

Depending on availability, up to 50 females of each species from each ½ hour period were dissected. Their ovaries were mounted on microscope slides and the mosquitoes were classified as parous or nulliparous by the condition of their ovarian tracheation (Detinova, 1962).

Temperatures at the collecting station were recorded at the start and end of each ½ hour period. Also, notes were made on the movements of mosquitoes from and into a "walk-in" red box. This box was six feet tall, six feet deep, and four feet wide, and was open at one end. It was painted red inside and out, and was permanently located about 50 yards from where biting collections were made. To measure the relative abundance of *Culex* and *Anopheles* mosquitoes, all resting mosquitoes were aspirated from the box upon completion of each all-night series of biting collections.

RESULTS AND DISCUSSION.–Hourly biting collections on a night in July, 1971, are shown in Table 1. Although collections were not particularly large, a variety of species were encountered and there was a uniformity of occurrence of peaks of activity near sunset. With some species a second peak of activity occurred near sunrise. Sunset occurred at 1935 and sunrise at 0455.

Figure 1 shows all-night biting collections of *Anopheles freeborni* Aitken on four nights. This species had strong peaks of activity near sunset and again near sunrise, and morning peaks occurred at temperatures as low as 51° F. Bailey and Baerg (1967) reported a threshold of about 50° F for strong flight by this mosquito.

The timing of peaks correlated closely with the times of movement of *A. freeborni* from and into the red box. For example, when observations began on 22 August, many males and females were resting in the box. Movement of mosquitoes from the box was first noted about 25 minutes before sunset. By five minutes after sunset the number in the box was noticeably reduced, and ten minutes later only a few blood-engorged females remained, some of which remained in the box all night. Movement back into the box did not occur until about 35 minutes before sunrise. Greatest movement into the box was from 30 minutes before until 20 minutes after sunrise. But mosquitoes were still entering the box when observations ceased nearly 90 minutes after sunrise.

The described pattern of movement applies to *Culex tarsalis* Coquillett as well as to *A. freeborni*, and is essentially the same as recorded for these two species in Fresno County where their presence or absence in a shelter was recorded by time phase photography (Gjullin et al., 1963). (Biting collections of *C. tarsalis* on the night of 22/23 August are shown in Figure 4.)

In a number of studies (Corbet, 1961, 1962; Hamon et al., 1964; Coz, 1964), biting patterns of parous and nulliparous females have been plotted separately and have been found to be remarkably similar. Circumstances did not permit all females collected in the present studies to be classified as parous or nulliparous, but the data obtained suggest that parous and nulliparous females had similar biting patterns.

Each night was divided into equal thirds for comparison of parous rates, and rates and numbers of females classified are shown in Figure 1. On each of the first three nights in Figure 1, the parous rate was lower in the middle period than in the first or last period. On the first and second nights, the differences between the first and second periods were significant, also at the 5% level. There was no significant difference between the first and last period of any night. This pattern cannot be readily explained, and points

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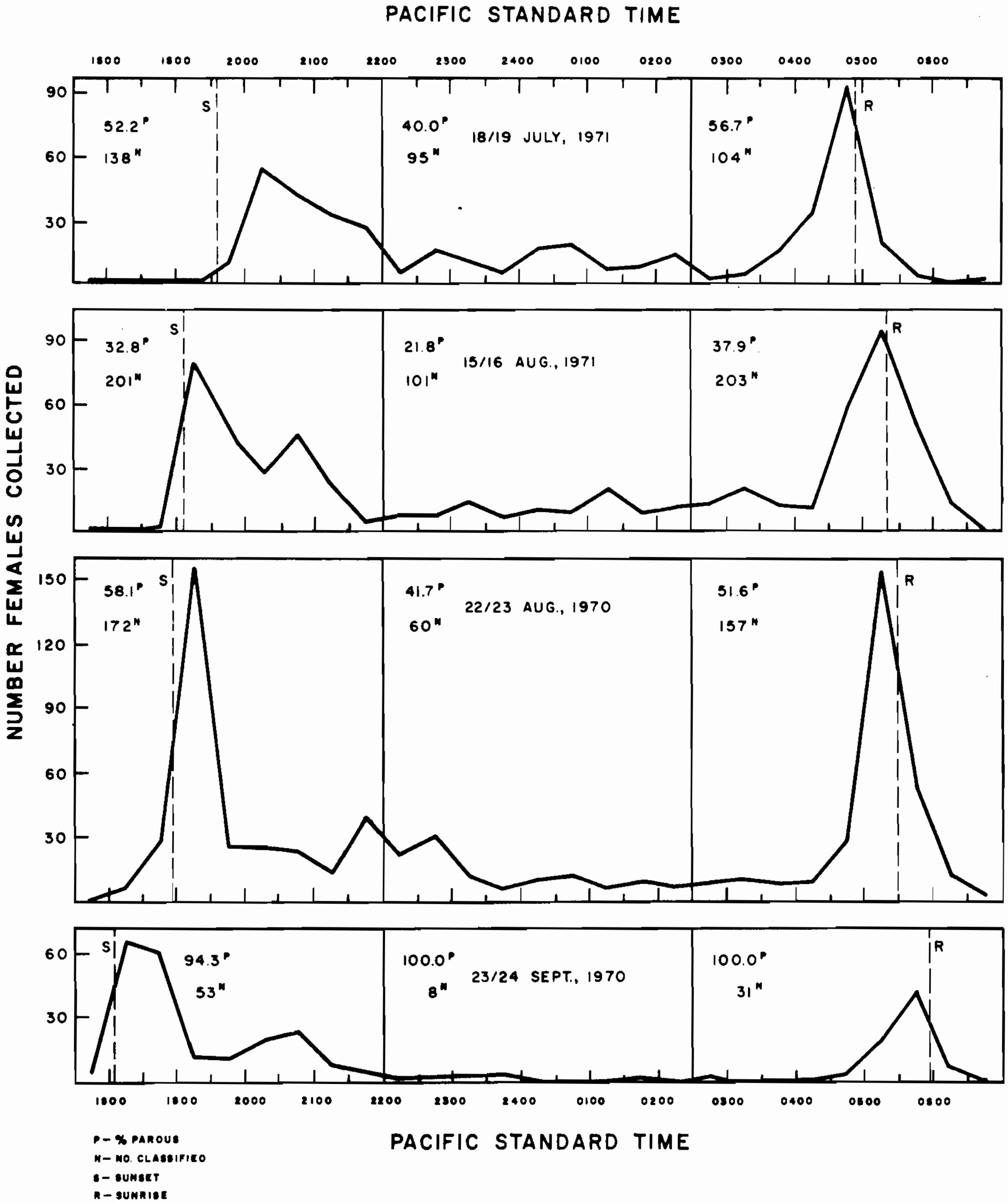

Fig. 1.—All-night biting collections and parous rates of *Anopheles freeborni*, Llano Seco study area, Butte County, California, 1970-71.

to the fact that little is known about the behavior of mosquitoes during the night when biting activity is reduced. It may be recalled that mosquitoes did not enter the red box between the evening and morning peaks of activity.

Nearly all females classified from the night of 23/24 September were parous. This could not be attributed to a lack of recent emergence, since 70% of 920 *A. freeborni* collected from the red box were males. Apparently newly-emerged females were not seeking blood meals but were preparing to overwinter. The findings of McKenna and Washino (1970) in the Sacramento Valley indicate that nearly all overwintering *A. freeborni* are nulliparous.

Figure 2 shows patterns of biting activity for *Aedes vexans* (Meigen), one of the most frequently collected speccies. *A. vexans* were taken almost exclusively in the early evening, and there was slight evidence of secondary activity near sunrise. This may have been due to prohibitive temperatures, since morning peaks of flight activity have been observed for this species (Knight and Henderson, 1967). According to studies in New Jersey (Bast, 1961), flight of

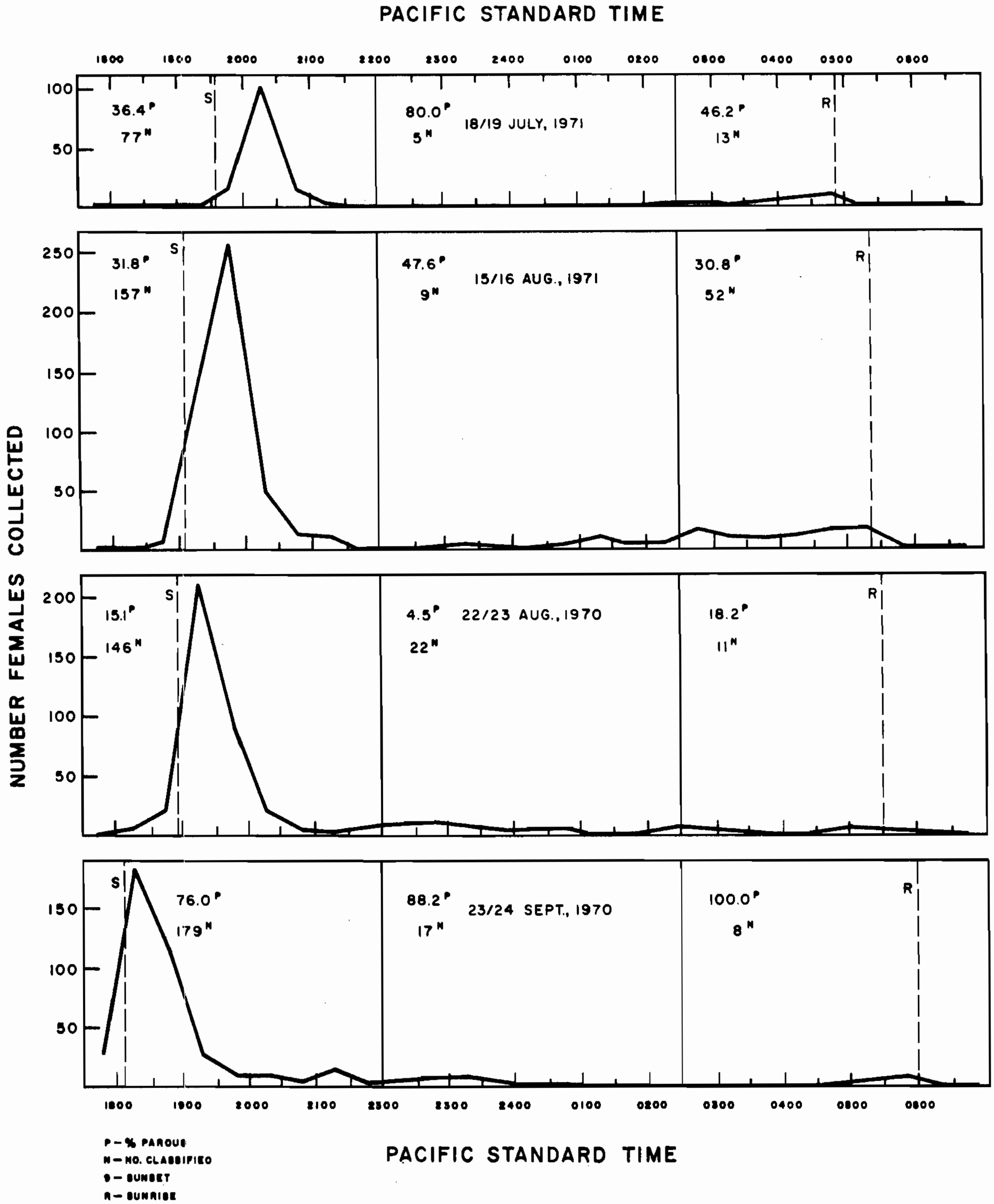

Fig. 2.–All-night biting collections and parous rates of *Aedes vexans*, Llano Seco study area, Butte County, California, 1970-71.

A. vexans is sharply reduced when temperatures fall below 64°F. Readings below 64°F prevailed throughout the last half of every night in Figure 2 except on that of 18/19 July, when a low of 67°F occurred near sunrise. Because of the limited activity following the evening peaks, meaningful comparisons of parous rates in different periods could not be made.

Collections of *Aedes melanimon* Dyar were large enough to be graphed on only two occasions (Figure 3). As with *A. vexans*, peaks occurred shortly after sunset. There was a small peak shortly before sunrise on the morning of 24 September, although the lowest temperature of the night (61°F) occurred at that time. A morning peak of biting activity has also been reported for *A. melanimon* in California by Miura and Reed (1969).

On the night of 23/24 September, the parous rate in the last period of the night was higher than in the first period at the 1% significance level.

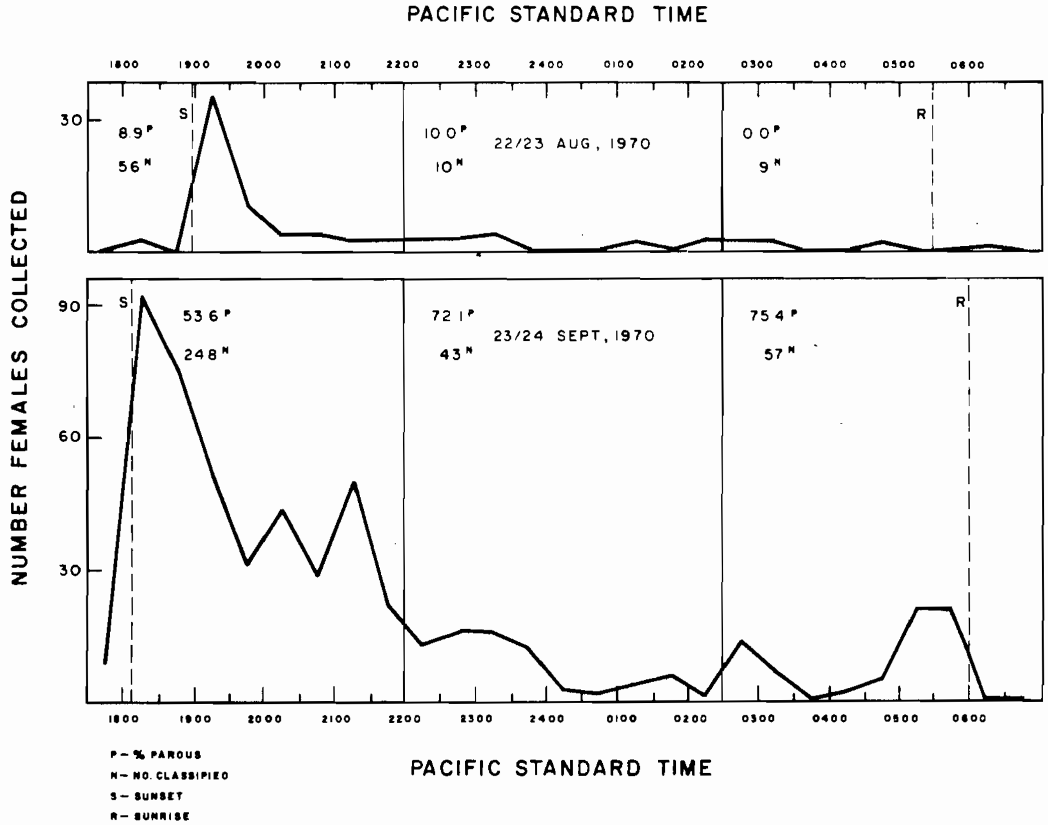

Fig. 3.–All-night biting collections and parous rates of *Aedes melanimon*, Llano Seco study area, Butte County, California, 1970.

The all-night collections showed an evening flurry of biting activity by *C. tarsalis* (Figure 4). Other studies (Bellamy and Reeves, 1952; Bailey et al., 1965) indicate that *C. tarsalis* may also have a morning peak of activity. Beadle (1959) made all-night biting collections of *C. tarsalis* and found that biting occurred throughout the night but was greatest shortly after sunset. He collected large numbers in Utah at temperatures as low as 56°F. Bailey et al. (1965) reported that biting activity in the Sacramento Valley was suppressed at temperatures below 65°F.

On the night of 15/16 August, the parous rate in the first period of the night was higher than in the third period at the 65% significance level.

Our collections of *C. tarsalis* were disappointingly small, perhaps because of low temperatures. However, despite read-

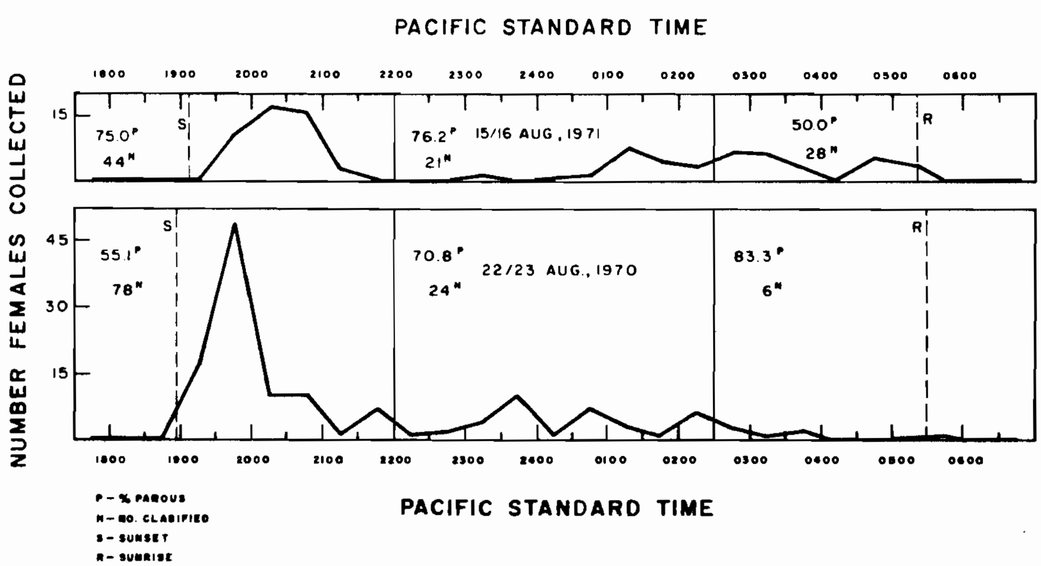

Fig. 4.–All-night biting collections and parous rates of *Culex tarsalis*, Llano Seco study area, Butte County, California, 1970-71.

ings as low as 51°F, many *C. tarsalis* moved into the red box near sunrise although little biting occurred. The data in Table 2 indicate that *C. tarsalis* are less anthropophilic than are *A. freeborni.*

CONCLUSIONS.–Data obtained on *A. freeborni, A. vexans, A. melanimon*, and *C. tarsalis* show that all of the species have peaks of biting activity near sunset, and that *A. freeborni* also bites actively near sunrise. Data from other studies indicate that the two *Aedes* species and *C. tarsalis* also have morning peaks under permissive conditions.

This predictable type of activity differs from that often exhibited in daylight hours by the two *Aedes* species. The rhythmical activity near sunset and sunrise probably is influenced both by an internal rhythm and by external environmental changes. The daytime activity may be influenced largely by invasion or disturbance of the mosquitoes' immediate habitat by a suitable host.

There was no evidence for any species that biting by either parous or nulliparous females was concentrated in any particular time period. Limited data did suggest, however, that parous *A. freeborni* comprised a smaller portion of the biting population in the middle third than in the first or last third of the night.

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MOSQUITO CONTROL CRISIS IN THE CENTRAL VALLEY: WHERE DO WE GO FROM HERE?

Charles H. Schaefer

University of California

Mosquito Control Research Laboratory, 5545 East Shields Avenue, Fresno, California 93727

During the past five years most of my research efforts have been on the pasture mosquito problem in the Central Valley. In the following remarks, which I base largely on that experience, I realize many of my suggestions are things that some mosquito abatement districts are already doing and, in some cases, are well established parts of their programs. I also realize it is difficult to generalize about the overall problem because it differs in various parts of the State. Nevertheless, because of the current mosquito control crisis in the Central Valley and the severe reductions in money available for seeking solutions to this problem, we must consider the present situation in terms of the resources and current knowledge available to plan for the 1972 and 1973 mosquito control seasons. I will make no attempt to cover all of the numerous mosquito control problems of the Central Valley, but I will limit my comments to the control crisis involving insecticide-resistance in *Aedes nigromaculis* and *Culex tarsalis* populations.

INTRODUCTION AND BACKGROUND INFORMATION

Due to its complex agricultural enterprises and extensive low areas surrounded by mountains, the Central Valley became an ideal mosquito breeding basin. In spite of this, inhabitants here have received the world's best mosquito control. Unfortunately, it appears the degree of mosquito control has been too good. The frequent, successive applications of insecticides, year after year, have led to intensive insecticide-resistance in two of the most important mosquito species. Now no promising new insecticides are apparent for use in the next several years. Should the MAD's now be blamed for this result? No, only the naive will make such a claim because there are complex reasons which explain the origin of the current situation. What are the factors that led to such heavy emphasis being placed on chemical control? There are several, and they are interrelated. The complexity of these interrelationships must be understood if we are to properly assess the problem and decide on future courses of action.

Many of the MAD's of the Central Valley began extensive operations at the end of World War II. At this time a new miraculous chemical, DDT, was available, and also aircraft application soon proved to be an effective means of treating large acreages of mosquito breeding areas.

Long term inhabitants of the Central Valley were elated over the resultant dramatic relief from mosquito harassment, while newcomers, undoubtedly, did not even realize the Valley once had a massive mosquito problem. By 1949

(Smith 1949) DDT resistance had been documented in Kern County, but prominent experts were convinced that before resistance could become so intensive as to greatly reduce the effectiveness of operational spray programs, technology would develop new chemical agents as replacements. Unfortunately, in 1952 when a severe epidemic of Western Equine Encephalitis struck and the chlorinated hydrocarbon insecticides were almost useless, replacement chemicals were not yet available. Attempts to suppress *C. tarsalis* populations by ground applications of oils were futile because of the magnitude of the breeding areas. Thus, the epidemic could not be contained. But later in 1952 MAD's obtained the first of the commercial organophosphorus insecticides, and it appeared that, even though there had been an unfortunate gap between the availability of useful chemical control agents, technology had succeeded. Thus, the regular spray programs continued successfully in the same effective way as they had in the past. At the same time when MAD's were establishing their operational spray programs, they also developed programs for reducing mosquito breeding sources, e.g., construction of drainage ditches and sumps to the limit of available manpower and equipment. Unfortunately, this program is expensive in the short term consideration and, therefore, has never been fully implemented.

Another economic factor of considerable relevance to this problem is that the chemical insecticides MAD's became accustomed to using were not only effective and safe but also were relatively inexpensive. The reason for the low expense factor was there were no exclusive patents on some compounds, and costs for their registration were relatively low. The absence of exclusive patents on some of the most effective compounds, e.g., parathion, resulted from their discovery in Germany during World War II and their release, free of patents, by the victorious Allied Nations after the collapse of the Third Reich. This led to commercial ventures to manufacture and market the compounds at very competitive prices.

Excellent mosquito control has conditioned people to a life free of mosquito problems and the expectation that the same should continue. This situation is similar to that of the housewife who has experienced an era of insect-free produce and will tolerate no change. Landowners whose agricultural practices produce mosquitoes have become accustomed to MAD's taking care of mosquito problems regardless of the breeding sources or the frequency with which the problem recurs. The appearance of organophosphorus-resistance was documented in 1958 (Lewallen and Nicholson, 1959). Since then MAD's have experienced a gradual loss in usefulness from a whole spectrum of organophosphorus larvicides so that presently there are many areas where mosquito larvae can no longer be controlled. There is still a general disbelief on the part of many mosquito producers, and even some MAD trustees, that the resistance problem has reached a critical stage.

Several years ago at the request of the CMCA Research Committee, our laboratory investigated why insecticide-resistance always seems to start in alkaline pasture areas. The conclusions of that study were presented at the 1968 Annual Conference (Schaefer and Dupras, 1968) and were as follows: Water quality of San Joaquin Valley alkaline pastures does not have any practical effect on the performance of organophosphorus larvicides. However, it is apparent there is a significant relationship between irrigated pastures and control difficulties. The pastures in question are on soils which have poor drainage; these lands are very difficult to farm and, therefore, are usually maintained as irrigated pastures rather than being rotated to higher return crops, such as occurs in other areas. The maintenance of irrigated pastures in an area creates a perennial mosquito problem and the need for chemical treatments. This repetitive chemical pressure slowly eliminates those members of the population that are susceptible to the insecticide used, and there is a slow but steady increase in individuals that are resistant. Eventually a highly resistant population is formed. Insecticide-resistance first appears in these marginal farming areas because it is here that more chemical treatments are made; and, therefore, the selection process takes place faster than in other areas. Of course, the resistant populations spread, and gradually a significant control problem results.

The economics of pesticide development have changed greatly, not only because of the risk of insecticide-resistance but also due to the greatly increased registration costs. During the past five years our laboratory has evaluated numerous candidate insecticides as potential mosquito control agents. Only one of these, Chevron RE11775, a carbamate, showed real promise for the operational control of our highly resistant strains of *A. nigromaculis* and *C. tarsalis* (Schaefer and Wilder 1970). Unfortunately, Chevron Chemical Company cannot justify development of this compound on the basis of the present mosquito control market, and no means appear to be available for California to subsidize the development of the compound so that it could be used during an epidemic. In addition, during the past two years chemical companies have almost stopped submitting new organophosphorus and carbamate compounds for testing as mosquito control agents. No new compounds are presently under commercial development that would be effective in controlling our highly resistant strains. This means MAD's cannot expect to have any new larvicides available for a minimum of several years. The only recourse available is for us to change our approach to mosquito control.

During the past year MAD's and supporting public agencies have sincerely tried to explain the mosquito control problem to the public and to those who are largely responsible for producing the mosquitoes. I am sure this program has done some good, but I am also convinced that hard-core abusers of water and land management have not been impressed and might have even become militant in the defense of their practices. To document these statements I would like to share several personal experiences: (1) During the summer of 1971 I spent several hours discussing the mosquito control crisis with a man who owns and manages numerous sections of land in Tulare and Kings Counties. His holdings include large acreages of irrigated pasture, many of which cause difficult mosquito problems. I explained to him it was my responsibility to conduct research to find newer and better techniques which MAD's and landowners could use in order to reduce the mosquito problem and, in addition to testing new insecticides, our laboratory was working on ways to improve water penetration through the use of soil and water amendments. I then asked this man to tell me what approach he would take, if he had my job, in order to find a practical solution to the pasture mosquito problem. His answer came after a long pause and was rather revealing. He said that until more careful irrigation practices could be implemented, nothing could really change. Also, while he would be willing to cooperate on experimental plots, he could not afford to change the general management of his properties because the margin for profit was too low and thus the financial risk too high for him to substantially increase the effort necessary for better control of water and land. He felt he would eventually be forced to make such changes, but until that time the general practices in current use would continue. (2) Generally, I have found when one explains the mosquito problem to landowners, they are very sympathetic and will go out of their way to cooperate in conducting experiments. However, one morning when I approached the superintendent of a large property which is notorious for producing mosquitoes, an interesting experience occurred. I explained to him that I would like to make experimental applications of some new chemicals on parts of an 80-acre field, which was currently being irrigated and contained large numbers of mosquito larvae. I asked if it would be possible to move about 100 head of cattle from the field being irrigated into an adjacent dry one. He refused, stating that mosquitoes will be produced no matter what you do and all these stories on the radio about mosquito problems were just attempts of the government to harass the man who had to pay the taxes. I then asked him if he realized that when cattle were left in fields that were under irrigation, or still wet, not only did soil compaction occur but the numerous hoof prints destroyed the level of the field and formed pockets which enhanced mosquito breeding conditions. He answered that it did not matter at all whether cattle were on lands that were being irrigated, mosquito breeding was no worse when land was unlevel, and controlling mosquitoes was a problem of the local MAD and not of the landowner. I then explained that the Health Code did have provisions through which the MAD could force him to improve conditions, but this was regarded as a last resort, and all of us involved in mosquito contorl were trying to solve the problem in a cooperative way that would allow for improvement in land productivity as well as public health conditions. He replied that his lands did not need improving and nobody was going to force anything on him. These two examples are based on actual experiences, and an attempt has been made to describe them truthfully. They are indicative of the attitude of those who I refer to as "hard-core abusers" of water and land management.

During the past year the Bureau of Vector Control has hired several engineers for the purpose of consulting with MAD's on specific mosquito problems and making specific recommendations to landowners. Many personnel are also available from the U. C. Agricultural Extension Service who can help in this endeavor. The biggest limitation of this approach is the fact that farmers themselves are experts at land preparation and water management. No one has to advise a grower that when water stands for long periods of time on the low end of his cotton field, there is a risk the plants will be stunted or "drowned-out." As long as there is an economic incentive, management of land and water is generally good and mosquito control problems are minimal.

During the summer of 1971, many of us went on a special field trip to an area approximately 20 miles west of Delano, formerly called Smith's pastures. This area has over 12,000 acres of pastures and has been well known to many of us as a place where we could find extremely high mosquito populations at any time during the summer field season. However, during the two past years a private company has taken over the management of these lands for the owner. In an attempt to increase profits, lands have been reworked and leveled, a great deal of attention has been given to the irrigation practices, a pattern of livestock rotation has been established, and some lands have been seeded with various mixtures of plants in order to improve yields. While some mosquito production still occurs in this area and some chemical treatments are still made, the reduction in mosquito production has been phenomenal. In fact few mosquitoes were apparent during our field trip, while in past years it took an act of daring for one to step out of a closed car in the same area. This is an example of the extent of improvement that can be achieved if an economic incentive is present. It seems it is necessary, in those situations where no positive economic incentive can be made apparent to a repetitive mosquito producer, that a "negative economic incentive" be instituted, i.e., a financial penalty.

WITH THIS BACKGROUND INFORMATION IN MIND, WHERE DO WE GO FROM HERE?

By WE, I refer to all of us who are directly involved in mosquito control activities. This includes MAD personnel and trustees and the supporting research and service personnel of various agencies, including the California Department of Public Health, the USDA, and the University of California. Since WE are involved in the problem together, we should each examine our particular responsibilities and critically evaluate whether or not we are carrying "our part of the load." Mutual criticism is in order, but we must be careful that this criticism is constructive and we do not simply indulge in a game of blame shifting. I believe the current mosquito control crisis is one in which all of us have a share in the blame. We all have and could give valid explanations for our past performances, but instead let us examine what we can and should do from this point on in order to improve the situation. First, I will summarize the current situation as it appears to me:

1. During the past one-quarter of a century, organic insecticides have provided an inexpensive, safe, and effective means of suppressing mosquito breeding.
2. It has become expected of MAD's in the Central Valley that they "clean up" any source of mosquito production no matter how extensive a given source is or how frequently it recurs.
3. The current insecticide-resistance levels in *A. nigromaculis* populations throughout most of the Central Valley represent a severe control crisis for this highly important pest species
4. The current insecticide-resistance levels in *C. tarsalis* populations in the San Joaquin Valley represent a severe control crisis for this encephalitis vector. Should we experience an encephalitis crisis in the next several years, we probably will not be able to prevent *C. tarsalis* populations from reaching levels which are efficient for virus transmission, and therefore an epidemic could result. Insecticide-resistance in *C. tarsalis* is spreading northward, and the Sacramento Valley will be confronted with a similar situation within the next several years. If we should experience an enceph-

alitis epidemic, the Federal Government will not be able to eliminate it by simply sending in multi-engine aircraft to disperse ULV applications of malathion--a disgusting misbelief still held by many people who do not understand the degree of insecticide-resistance in *C. tarsalis* populations.

5. At the present time the chemical industry is in a "void period," and most companies have given up trying to develop new organophosphorus or carbamate compounds. There are NO new chemical insecticides under commercial development that would be operationally feasible for MAD's in the Central Valley to use in the same type of control program that has been in general practice. Therefore, it may be several years before any new, safe, and effective compounds are available.
6. While there are some new modes of chemical action that are being explored in research programs, it will be several years at least before any of these become available. In addition, we can expect the same resistance problems with any new chemicals that are developed, and we must find ways to reduce insecticide pressure on mosquito populations. While fresh leads on chemical agents are available, their development will be slow because the requirements for registration are becoming exceedingly complex and expensive, and the efforts of those of us in research are being constantly reduced through budget reductions.
7. While nonchemical methods of mosquito control are of great importance, chemical control will remain a major factor in mosquito suppression; for example, it is unlikely that any other tool now available could be as effective during one of the severe flooding situations we periodically must deal with.
8. The source reduction activities of MAD's have been extremely valuable programs. While these programs are expensive, they have long-lasting effects and are highly worthwhile.
9. Currently there are no biological control methods that might be used effectively for the control of *A. nigromaculis* or *C. tarsalis* on irrigated pastures or related temporarily flooded habitats. However, future research may well lead to the development of techniques which will permit effective use of pathogens, predatory arthropods and fish.

WHAT CAN BE DONE IN THE NEXT SEVERAL YEARS FOR MAD'S THAT ARE NOW EXPERIENCING SEVERE CONTROL PROBLEMS?

1. REEVALUATION OF RESEARCH PROGRAMS: Research programs must be reevaluated and efforts directed to the speedy exploitation of the most promising leads. In this connection our research program at Fresno has already been considerably revised. During the next year all five of our permanent staff will work that lead which we now consider to be the most likely to yield a practical result: the use of compounds related to natural insect developmental regulators as mosquito control agents. For this study we will simultaneously determine the effects of the most promising compounds on target and nontarget organisms and define their chemical stability. A paper discussing this specific project was presented earlier at this meeting. This represents an important change in our research policy in that we will be placing a high percentage of our effort on the single, most promising line of investigation, whereas before we had scattered our efforts on numerous projects. We will continue to test the few candidate insecticides which we receive and obtain data from the field plots which have been treated with soil amendments in previous years. However, the bulk of our effort will be concentrated as described above.

2. PUBLIC INFORMATION PROGRAMS: All of us must continue to keep the public informed about this control crisis. It is important that the public information programs which have been active in the past year should continue from the MAD level and those of us in "service capacities" continue to support these programs, as well as issue timely and accurate releases on our own. In this regard, all of us should actively oppose and discredit any naive individual or individuals who release information on simple, new approaches that are purported to be THE ANSWER to mosquito control problems. The public cannot understand how there can possibly be a severe mosquito control problem as long as these periodic, simple solutions keep appearing throughout our news media.

3. SOURCE REDUCTION: The source reduction programs which have always been a basic part of mosquito abatement activities should continue to be emphasized to the maximum possible extent.

4. POSITIVE APPROACH WITH COOPERATIVE MOSQUITO PRODUCERS: In addition to the regular source reduction programs, MAD's should utilize to the fullest extent the services of advisors who can offer help to landowners who have specific mosquito breeding problems. However, these service personnel can only offer technical advice, and therefore their usefulness is limited. This is in keeping with the old saying, "You can lead a horse to water, but you can't make him drink." There are many mosquito producers who will cooperate when the problem is clearly explained. These are the same people who are affected by public information programs and who will consider technical advice when it is obvious an attempt is being made to solve a serious problem in a positive manner. Successes through such cooperative efforts should be publicized.

5. DEALING WITH "HARD-CORE ABUSERS": This brings me to the difficult question of what MAD's should do about those mosquito producers who refuse to cooperate. While I recognize that some MAD's have dealt fairly successfully with this problem and others are trying, this is a significant problem that is not being handled adequately by many districts. Many mosquito producers still have the philosophy that MAD's are tax-supported agencies and therefore are responsible for cleaning up any mosquito breeding problem that occurs no matter what its cause. This attitude is not new and if you need refreshing on this subject, read the paper presented by Frolli (1971) at this conference last year. The basic problem is not different from that which air pollution control authorities have been handling. In many instances they have had to ultimately tell offenders to reduce pollutants in the air or water effluents to tolerable levels or else be subjected to punitive measures. It is reasonable to consider significant mosquito production as a form of environmental pollution which is not tolerable to the public. The problem of dealing with gross

negligence in the use of water and land cannot be solved through research but rather is a political problem which the trustees of MAD's are responsible for solving. For example, we are studying methods of improving water penetration on poor soils; but even if we find a practical method which will yield a 50% improvement, this will not be of any value if 500% too much water is applied to a given field. The management personnel of MAD's cannot effectively deal with "hard-core mosquito producers" unless their respective trustees have formally adopted reasonable but firm policies. But how fast and through which specific means should MAD's tackle these so-called hard-core offenders? I do not know, and obviously such details have to be worked out by individual districts in relation to their own situations. However, to further ignore or neglect this problem, in districts which currently have severe control difficulties, is an act of irresponsibility on the part of the respective trustees. There is no question it will be difficult to take such action, and also such an approach is distasteful. Unfortunately, in many situations this is the only approach that remains, and it is irresponsible to do nothing. Furthermore, the fact that hard-core offenders are allowed to get away with their type of management of land and water certainly does not help the attitudes of others who might be willing to initiate changes in their agricultural practices.

6. CAREFUL USE OF THOSE PESTICIDES WHICH ARE STILL EFFECTIVE: MAD's still have useful pesticides available, but in the areas of severe resistance the situation appears to still be worsening. Baygon® is still effective against adults of highly organophosphorus-resistant populations. While we have not been able to document Baygon resistance by l-d-p lines, we know the knockdown time of adults under operational conditions is longer than it used to be when the use of Baygon was initiated. I certainly am not recommending that insecticide applications be stopped, but I do strongly urge that discretion be used. For example, it is known that an adequate amount of Baygon in oil is effective against organophosphorus-resistant larvae (Sjogren and DeWitt, 1971), but to pressure larval populations, as well as adults, with Baygon would not only be expensive but would also be unwise under present circumstances.

7. USE OF OILS: Oil larviciding by ground equipment should be used whenever practical. This might effectively extend the potential usefulness of organophosphorus compounds in many areas. Aerial applications of relatively high volumes i.e., over two gallons/acre of oil, do not appear to be practical at present. The problems involved with dispersing lower volumes evenly across target areas are still not worked out for routine operational use. Current studies on the effectiveness of various oils are in progress and should continue.

8. REASONABLE MOSQUITO CONTROL: MAD's cannot be expected to provide a "mosquito-free environment," and therefore people simply have to tolerate some mosquitoes. It is unrealistic for an MAD to attempt to provide complete mosquito control.

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WATER QUALITY CONTROL AND MOSQUITO ABATEMENT

Dwight C. Baier

State Water Resources Control Board

1416 9th Street, Sacramento, California 95814

The Porter-Cologne Water Quality Control Act, hereinafter referred to as Porter-Cologne, became effective January 1, 1970. It succeeded the more lenient Dickey Act of 1949 and has been said to be the toughest pollution law in the nation. While agricultural wastes had always been deemed to be industrial wastes under the old Dickey Act, Porter-Cologne increased the responsibility of the control agencies to abate this source of pollution.

A brief look at the structure of the water quality control agencies may be instructive to understand how they will affect you, in the business of mosquito control. The State is divided into nine regions, which very roughly are the watersheds of the State. Water quality control in each region is entrusted to a regional board, consisting of nine members appointed by the Governor to serve without pay for four years and to represent segments of our economy as opposed to geographical areas. For example, membership is as follows:

1. One person associated with water supply, conservation and production.

2. One person associated with irrigated agriculture.
3. One person associated with industrial water use.
4. One person associated with municipal government.
5. One person associated with county government.
6. One person from a responsible nongovernmental organization associated with recreation, fish or wildlife.
7. Three persons not specifically associated with any of the foregoing categories, two of whom shall have special competence in areas related to water quality problems.

In addition to the nine regional boards, Porter-Cologne designates the State Water Resources Control Board to consist of five members who are paid employees of the State. Two are registered civil engineers, one a lawyer, one expert in water quality and one without special expertise.

In the normal course of events, the day-to-day control of water quality is done by the regional boards. They do not all approach problems in the same way, but they do generally follow policies of the State Board.

Recently, the State and Regional Boards have been giving increased attention to agricultural wastes. They are aware that more than 85% of the State's diverted water is used for agricultural pursuits. They know that an effective water quality control program must cope with wastewaters produced by this prodigious industry. Accordingly, both the State and Regional boards have added agricultural expertise to their staffs and nearly a year ago the State Board formed the Agricultural Water Quality Advisory Committee, consisting of agricultural leaders throughout the State, to advise the State Board in matters of agricultural wastes. Meanwhile, research has begun to solve some of the vexing problems of wastes from agricultural operations. For example, one popular method of handling poultry manure is to flush it into a holding pond where it is stored for disposal at a propitious time. In order to determine the effect of this practice on the waters of the State, the State Board sponsored research to look at the permeability of the ponds, how much denitrification occurs in them, etc. The report from the project is now in the hands of the State Board and will be available shortly. It enables the regional boards to make recommendations relating to the use of holding ponds and to be reasonably confident that, if properly done, the practice will not endanger the waters of the State.

Some regional boards have been more aggressive in setting waste discharge requirements than others. For example, the Santa Ana Regional Board is now in the process of setting discharge requirements for some 400-odd dairies, mostly in the Corona-Chino area of the San Bernardino and Riverside counties. In that region, the staff of the Regional Board has been working through farmer organizations to find mutually acceptable solutions. In some counties, particularly in the San Joaquin Valley, contacts with dairymen have been mostly through county health departments and dairy inspectors.

What will the discharge requirements for dairies, chicken ranches and feedlots look like? All the details have not yet been worked out. However, it is clear that some changes will be made that will have a positive effect on mosquito abatement. For example, uncontrolled discharge of all liquid wastes from livestock operations will be stopped. The most likely method of handling these liquid wastes will be discharge to holding ponds. Eventually the ponds will be emptied by using the water for irrigation. Dairymen are likely to be required to have a certain acreage per cow on which they can spread their manure and they will be expected to spread the manure over that area. They will be expected to protect their property from sheet runoff, both that which falls on the manured area and that which might threaten to sweep through the manured area from higher ground.

Control of irrigation wastewater is a stickier problem than the runoff from livestock operations. The policy of the Board will be to encourage, in every way possible, the consolidation of the irrigation wastewater discharges. Ideally, of course, there will someday be a central valley drain which will quickly drain off these waters that now cause problems by breeding mosquitoes. These actions on irrigation drainage will be slower in coming than those for dairies, feedlots, chicken ranches and other livestock operations.

I have been pleased to have Marvin Kramer, Senior Vector Control Specialist from the Bureau of Vector Control and Solid Waste Management participating in our discussions on the livestock waste problems. Hopefully, in controlling waste discharges, we may accomplish the dual objective of mosquito abatement.

THE ALGAE, *CHARA* AND *CLADOPHORA*: THE PROBLEMS THEY CAUSE AND THEIR CONTROL[1]

Richard R. Yeo

University of California

U. S. Department of Agriculture and Department of Botany, 143 Robbins Hall, Davis, California 95616

Some attention has been given recently to the possibility of planting certain algae in lakes, ponds, canals, drains, and other large and small water systems to control mosquito larvae. The concept of using biological alternatives to chemicals is praiseworthy. However, consideration should be giv-

[1]Contribution of the Plant Science Research Division, Agriculture Research Service, U. S. Department of Agriculture, Bureau of Reclamation, U. S. Department of the Interior, Reg. 2, California Department of Water Resources, and California Agr. Exp. Station, Davis, California.

en to some of the potential problems that may follow inoculation of waters with algae.

The problems involve three species of algae, *Chara elegans* (A. Braun) Robinson, *Chara fragilis* Desvaux, and *Cladophora glomerata* (L.) Kutz. (hereinafter these are referred to as chara and cladophora). Chara, common in waters throughout the lower elevations of California, is most abundant in hard water. Single plants of chara look like bushy herbs with the up-right filaments anchored to the soil by fine rhizoids. Whorls of leaf-like branches bearing the reproductive structures, occur along the filaments. Chara reproduces sexually by zygospores (Prescott 1968) and asexually by dormant filament apices and bulbils which form in the soil (Fritsch 1961). Chara is distinguished from other similar algae (*Nitella* spp. and *Tolypella* spp.) by the strong musky odor emitted from crushed filaments and by certain features of the vegetative and reproductive structures.

Cladophora is the most common filamentous alga in California's water transport systems. It is frequently caught by debris or aquatic vegetation along canal and drain bottoms, and develops trailing masses up to 15 feet long. Dense mats of cladophora often lie on the bottom of lakes and ponds during cold cloudy weather, and later float to the surface when the sun stimulates photosynthesis and the production of gaseous oxygen. The mats consist of masses of branched filaments whose cells are filled with photosynthesizing green clorophyll. Cladophora is distinguished from several other similar algae by the rough, non-slimy feeling that occurs when it is rubbed between the fingers. The plants are propagated asexually by quadriflagellate zoospores and thick-walled resting cells called akinetes. Sexual reproduction is isogamous and is accomplished by the union of biflagellate gametes (Smith 1950). Growth of cladophora is continuous and drifting plant fragments rapidly enhance the distribution of the alga throughout a water system.

The presence of these algae creates a variety of aquatic nuisances which require remedial measures:

1. Both algae impede the flow of water in canals and drains; often preventing the delivery of badly needed water to crops. Floating masses of cladophora are usually conspicuous at siphons, trash racks on turnouts, and along the waterline of cement-lined canals.

   Chara is less conspicuous to the eye; however, it still causes greatly reduced water flows because of the six foot long growths that have been observed.

2. Fragments of cladophora clog the suction filters of irrigation pumps. The smaller fragments pass through irrigation pipes to sprinkler heads and plug the orifices. (Howard and Berry 1933; Mackenthrun et al. 1964; Swartz 1955; Whipple et al. 1948).

3. Rice crops are robbed of nutrients by rapidly developing blooms of cladophora and dense infestations of chara.

4. The use of recreational water for boating and swimming is restricted by the mats of cladophora. (Howard and Berry 1933; Mackenthun et al. 1964; Swartz 1955; Whipple et al. 1948).

5. Chara imparts a fishy odor to drinking water (Palmer 1959).

6. Cladophora often looks and smells like untreated sewage (Hynes 1966), or when decomposing, it has a septic odor (Howard and Berry 1933; Mackenthun et al. 1964; Swartz 1955; Whipple et al. 1948). Property values of farms, ranches, and suburban home developments with lakes and ponds are reduced as a result of extensive algal growths.

7. The perpetual growths of algae and other aquatic vegetation hasten eutrophication of water by the accumulations of organic matter on the bottom.

8. The efficient operation of a new federally-operated salmon spawning facility at Red Bluff, California has been hampered by masses of cladophora covering the surfaces of the fine-mesh screens used to contain young salmon fry. Fragments of the algae also interfere with accurate counting of fry (Howard and Berry 1933; Mackenthun et al. 1964; Swartz 1955; Whipple et al. 1948).

9. Mosquito abatement districts which raise and harvest mosquito fish (*Gambusia affinis* Baird & Girard) occasionally find that separating fish from mats of cladophora is a time-consuming and costly operation (Howard and Berry 1933; Mackenthun et al. 1964; Swartz 1955; Whipple et al. 1948).

Several chemicals are available for controlling cladophora and chara. Copper compounds, including copper sulfate pentahydrate (hereinafter referred to as CSP) and cuprose citrate (which is a combination of CSP and citric acid), are safe to use in potable water. CSP and cuprose citrate will control cladophora in static water at concentrations ranging from 0.25 to 1.0 ppm. CSP is used in canals either by applying amounts equivalent to two pounds per cubic feet per second of water or by applying continuously to give concentrations up to 1.0 ppm. Common methods of application in static water include broadcasting the crystals over the alga mats or dragging bags of crystals behind a boat. In flowing water, bags containing the crystals can be suspended along canals every two to four miles, large quantities can be "dumped" into the water, or fed at low levels into the water using automatic feeders. Both compounds will kill trout. Other kinds of fish are usually not harmed at these rates.

The dimethylcocamine salt of endothall will control cladophora at a concentration of 0.2 ppm applied continuously for two to eight hours. The treated water must be held for seven days before it can be used for irrigation, watering livestock, or domestic purposes. The chemical is often applied by injecting the herbicide concentrate directly into flowing water at some point of turbulence, or injecting next to the prop wash of an outborad motor in static water. It will not harm most fish at this rate of application.

Dichlobenil is especially effective on chara, and will also control cladophora. The herbicide is granular and is applied over the water by hand or by a granule spreader at rates ranging from seven to ten pounds active ingredient per surface acre. The treated water should not be used for crop irrigation, human consumption, or watering livestock until 90 days after treatment. Fish are not harmed by dichlobenil, but they should not be eaten for 90 days.

Acrolein is effective on both chara and cladophora at 0.62 to 0.95 ppm in flowing water and at 0.66 to 5.2 ppm in static water. It should not be applied in water used for watering livestock or human consumption. The injection period in canals usually lasts over an eight hour period, but it may be varied according to the amount of algae and other aquatic weeds present. Acrolein is toxic to fish.

This discussion has acquainted you with the problems that exist from the presence of chara and cladophora in different aquatic situations, and the control of these algae using several algicides. It is hoped that the consequences of widespread planting of these algae to control mosquito larvae will be given some consideration.

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CERTIFICATION OF VECTOR CONTROL PERSONNEL IN CALIFORNIA

Gardner C. McFarland

Southeast Mosquito Abatement District

9510 South Garfield Avenue, South Gate, California 90280

There is a great deal of interest at all levels of government and in the private sector in the improvement of the quality of life in relation to the environment in the United States, and for that matter, in the world. This interest is shown in many ways at all levels in regards to various aspects of the environment. The interest is evidenced in the fields of air pollution, water pollution, and ground pollution and would include aspects of noise and aesthetics. We, today, are particularly interested in the environment from our own standpoint of vector control. I use the term vector control in a general sense and would include all vectors we are responsible for such as mosquitoes, gnats, and flies, as well as nuisance organisms such as chironomids, wasps, and other pestiferous organisms. As you are well aware, the interest of the general public has been whipped to a frenzy of concern in many areas. Some of this alarm and hysteria is justified and much of it is not. The start, more or less, of this concern could be placed at the doorstep of the late Rachel Carson and continues on in an expanding form by statements and actions of responsible scientists as well as some irresponsible scientists together with diatribes from what are popularly known as "pseudo-ecologists". Unfortunately, also, the misinformed, inadequately informed, or self-seeking individuals have gained the popular press.

One aspect of the statements and charges has been the questioning of the abilities and capabilities of vector control personnel —— those people who direct vector control programs as well as those who carry out the programs in the field. Some of the questioning of the capabilities and competency of such personnel may have some basis in fact since some programs carried out by official agencies, not vector control, in areas of the United States may have been less than professional. More important, however, is the fact that even though vector control workers are, by and large, competent, a great many have no proof of this competency. Organizations hiring such personnel are, therefore, subject to criticism particularly by uninformed but vociferous so-called protectors of the environment.

As the result of such situations, the California Mosquito Control Association initiated studies with the Ways and Means Committee to study possible necessity of some form of certification/registration or licensing that would insure an answer to this criticism. These studies started in 1966 and have continued to date. The first study included the following findings and are quoted:

I. "Certification and/or registration may be accomplished by at least three different methods. These are:
   - A. Registration as a professional person under the Department of Vocational Standards.
     1. This would require an act by the State Legislature which would add as appropriate chapter to the California Business and Professional Code.
   - B. Certification of competence as a vector control worker by the State Department of Public Health.
     1. This would be accomplished by legislative amendment of the California Health and Safety Code or the California Administrative Code.
     2. It might also be accomplished on a voluntary basis by contractual agreement between individual districts and the State Health Department.
   - C. Certification of proficiency as a mosquito control worker by the California Mosquito Control Association.
     1. This could be implemented by the appointment of an Examining and Certification Committee.
     2. Certification by this method would be voluntary. Individual workers might become certificated at their option, or the governing board of a local control agency could establish a policy requiring its district personnel to obtain certification."

RECOMMENDATIONS.—The 1966 committee reached a concensus and presented the following recommendations for consideration:

A. The California Mosquito Control Association should promote a Registration Act. by the State Legislature, establishing a profession to be known as Vector Control Officer or other appropriate title. This Act should be included as a chapter in the California Business and Professional Code as administered by the Department of Professional and Vocational Standards.

1. This Act should follow the normal format of typical chapters in the Business and Professional Code.
2. It should specifically provide for: a Board of Examiners; penalties for violation; revocation of registration for cause; and a reasonable schedule of fees for administrative costs.
3. Specified penalties to be paid by non-registered persons working as vector control officers would be provided, together with provisions for action to be taken against an agency or company who knowingly employs unregistered persons to perform vector control work.
4. Appropriate grades and classes of workers, including trainee positions, should be provided for.
5. In order that the Act would not be retroactively detrimental to persons presently engaged in this work, a "grandfather clause" would be included to provide automatic registration of such persons at the time registration of the profession became effective.
6. Vector control work would be defined as follows: "Any work, activity, or pursuit, having as its purpose, design, or intent the abatement of control of insects of public health significance on an area-wide basis in any area having 100 or more inhabitants."
7. State Health Department workers and U. S. Public Health Service personnel engaged in vector control work in the performance of their official duties, and persons doing vector control work on military installations under the direction of the military authorities, would be exempted.

B. If the general membership of the Association finds the concept of profession registration too revolutionary to gain substantial support at this time, then one of the alternate methods should be pursued and every effort should be made to eventually attain true professional status through evolutionary process."

The Board of Directors' action was to recommend further study by the next Ways and Means Committee meeting.

II. In 1967, a preliminary report was submitted by the Ways and Means Committee to the Board of Directors. This study described in detail the procedures used by vocations and professions to be certified and regulated by the Department of Professional and Vocational Standards. Registration of this type can apparently be obtained by one of three approaches. "In California there appears to be at least three general approaches to registration: (1) by initiative petition of the people; (2) by act of the State Legislature, either at the urging of the profession, or by pressures from interested citizens who feel that the general public requires this protection; and (3) departmental regulation by various departments of the State government where they are more or less directly involved in the activity. (Sometimes indirectly involved through subvention grants or other matching fund programs.)"

III. In 1968, the Ways and Means Committee stated that the "Intent and Objectives of a Certification/Registration/and Licensing program are: The prime intent of certification and licensing is to protect the public.

A. Chemicals used in present day mosquito and vector control programs can cause serious injury to man, his domestic animals, wildlife populations, and plants when handled and applied by persons who are not thoroughly familiar with the hazards involved and the measures to be taken to prevent injury.
   1. These present a hazard not only by direct contact, but also through pollution of the air, water, and food.

B. The second objective is the promotion of standards of proficiency in vector control which would include source reduction and other measures designed to take advantage of a knowledge of the ecology of the organism. This not only insures protection to the public from accidental injury by substances used in the control program, but also affords them protection from the diseases carried by the vector through accomplishment of the assigned duty of ridding the community of the animal responsible for the disease.

C. Certification should provide career opportunities and encourage young men and women to prepare themselves for this profession. Once standards are established, the colleges and universities could be encouraged to offer courses of study which would prepare these young people for a career in vector control. Persons already engaged in this work could determine what additional education, experience, and character traits would be required for their advancement within this field.

D. Certification would give professional status to the vector control worker and allow us as a group to determine what skills and experience are really necessary to accomplish a satisfactory job of vector control.
   1. If we do not take the initiative to preserve our identity by becoming truly professional, we run the risk of being "swallowed up" by some related profession. Even now the Sanitarians' Association seeks to include us in their group! It is not beyond the realm of possibility that Agricultural Commissioners, Pest Control Operators, Medical Entomologists, Sanitary Engineers, or some other professional group may also attempt to bring vector control workers under regulations formulated by them for the advancement of their profession.

E. Certification and regulation of the profession should serve to prevent a situation from arising which would cause the public to demand legislation imposing severe restrictions on the activities of local vector control programs."

IV. A very comprehensive paper on the subject was presented by Mr. John Brawley, Manager, Contra Costa Mosquito Abatement District, "Employee Certification/Registration/and Licensing –– Its Possible Place in Vector Control". This paper was presented at the Seminar on Management for Vector Control Administration, October 29, 1970, the Proceedings of which are a publication of the California Mosquito Control Association.

Recently, the importance of consideration of Certification/Registration/and Licensing was made evident in a speech by Dr. David D. Dominick, Assistant Administrator for Categorical Programs in Environmental Protection Agencies. Dr. Dominick's address was made to the Entomological Society of America at its Annual Conference held in Los Angeles, November, 1971, and I quote from his address: "For more than 30 years, we have nonchalantly introduced into our environment –– for the good of man –– a myraid of chemical, biological and physical contaminants with little idea of what we were doing in the long-run to ourselves or other life forms with whom we share this globe. The time has come when this must halt. We must begin to test new pesticides in advance. We must thoroughly consider not only short-term benefits, but long-range effects. We must be more specific about how these chemicals are applied and in what amounts. We must know where pesticides will be applied and by whom."

Dr. Dominick described in detail provisions of H. R. 10729 which has been passed by the House of Representatives and is now pending in the Senate. This Act is entitled, "The Federal Insecticide, Fungicide, and Rodenticide Act" with the purpose primarily to protect health and the environment defined as "Means of protection against any injury to man and protection to any substantial adverse affects on environmental values taking into account the public's interest, including benefits from the use of the pesticide".

In connection with this protection of the environment, included are provisions for Certified Pesticide Applicator which means any individual who is certified and authorized to use or supervise the use of any pesticide which is classified for restricted use. Excerpts from the Act include:

"SEC. 4. USE OF RESTRICTED USE PESTICIDE: CERTIFIED APPLICATORS.

A. CERTIFICATION PROCEDURE

1. FEDERAL CERTIFICATION. Subject to paragraph (2), the Administrator shall prescribe standards for the certification of pesticide applicators. Such standards shall provide that to be certified, an individual must be determined to be competent with respect to the use and handling of pesticides, or of the use and handling of the pesticide or class of pesticides covered by such individual's certification.

2. STATE CERTIFICATION. If any State, at any time, desires to certify pesticide applicators, the Governor of such State shall submit a State plan for such purpose. The Administrator shall approve the plan submitted by any State, or any modification thereof, if such plan in his judgement ––

   a. designates a State agency as the agency responsible for administering the plan throughout the State;
   b. contains satisfactory assurances that such agency has or will have the legal authority and qualified personnel necessary to carry out the plan;
   c. gives satisfactory assurances that the State will devote adequate funds for the administration of the plan;
   d. provides that the State agency will make such reports to the Administrator in such form and containing such information as the Administrator may from time to time require; and
   e. contains satisfactory assurances that State standards for the certification of pesticide applicators conform with those standards prescribed by the Administrator under paragraph (1).

B. STATE PLANS. If the Administrator rejects a plan submitted under this paragraph, he shall afford the State submitting the plan due notice and opportunity for hearing before so doing. If the Administrator approves a plan submitted under this paragraph, then such State shall certify pesticide applicators with respect to such State." The timetable for carrying out the provisions of the Act are as follows:

"A period of four years from date of enactment shall be provided for certification of pesticide applicators.

A. One year after the enactment of this Act the Administrator shall have prescribed the standards for the certification of pesticide applicators.

B. Within three years after the enactment of this Act each State desiring to certify pesticide applicators shall submit a State plan to the Administrator for the purpose provided by section 4 (b).

C. –––As promptly as possible but in no event more than one year after submission of a State plan, the Administrator shall approve the State plan or disapprove it and indicate the reasons for disapproval. Consideration of plans resubmitted by States shall be expedited."

The certification provisions of the Act appear to be voluntary for the states, however, financial inducements are made in the Act to provide Grants-In-Aid for training which are as follows:

"SEC. 23. STATE COOPERATION, AID, AND TRAINING.

A. COOPERATIVE AGREEMENTS. The Administrator is authorized to enter into cooperative agreements with States––

1. to delegate to any State the authority to cooperate in the enforcement of the Act through the use of its personnel or facilities, to train personnel of the State to cooperate in the enforcement of this Act, and to assist States in implementing cooperative enforcement programs through grants-in-aid; and

2. to assist State agencies in developing and administering State programs for training and certification of pesticide applicators consistent with the standards which he prescribes.

   b. CONTRACTS FOR TRAINING. In addition, the Administrator is authorized to enter into contracts with Federal or State agencies for the purpose of encouraging the training of certified pesticide applicators."

The Board of Directors of the California Mosquito Control Association appointed a 1971 Special Committee to review all past studies and to come up with concrete recommendations. The Committee completed the study and after much review and research came up with the following recommendations:

There were six possible avenues that could be followed:

A. Maintain the status quo which would be to do nothing.

B. Initiate legislative action for registration of mosquito and vector control personnel with provisions for such certification or registration to be placed in the Health and Safety Code administered by the State Health Department.

C. Certification by Professional and Vocational Standards of the State. This method is expensive and would cost those certified a total of approximately $50,000.00 per year.

D. Licensing for competency. A procedure for licensing pesticide applicators at all levels of government and the private sectors is in effect in Utah. The licensing is required for mosquito control personnel who are employees of Mosquito Abatement Districts in Utah with licenses by examination required annually. The licensing is a function of the Utah State Department of Agriculture.

E. Certification of competency of mosquito control personnel by the California Mosquito Control Association in conjunction with the Bureau of Vector Control and Solid Waste Management in California. This program was initiated in 1970 on recommendation of the Ways and Means Committee of the CMCA. The first course of training was completed in 1970 for all mosquito control personnel in the State. In March, 1971, the Ways and Means Committee recommended continuation of this training course at the original level in addition to an advanced level for those who had completed the original course. The Board of Directors adopted this recommendation as Policy.

The Certification/Registration/and Licensing Committee recommended to the Board of Directors at its December, 1971 Meeting that the Board action in March be reaffirmed and that all necessary steps be taken in 1972 to carry on training programs for certification of mosquito control personnel. This type of training and certification by the California Mosquito Control Association and Bureau of Vector Control does not have the mandatory requirement of State law. It does, however, indicate to interested people such as Legislators and concerned ecologists and environmentalists, competent or incompetent, that governmental personnel carrying on mosquito and vector control in California are interested in doing their work in such a manner that the environment, human, animal, and vegetable is being protected by competent people. It can be seen from the potential Federal legislation being promoted by the Environmental Protection Agency, that the day may soon be here which will require formal certification by the several States.

In this event mosquito and vector control personnel of governmental agencies will be ready and qualified by the on-going programs of the California Mosquito Control Association and Bureau of Vector Control and Solid Waste Management.

THE PRACTICAL ASPECTS OF A LARGE–SCALE FIELD TEST OF RICE FIELD MOSQUITO CONTROL

Eugene E. Kauffman[1] and James B. Hoy[2]

The Sutter-Yuba Mosquito Abatement District has a large acreage of rice, approximately 80,000 acres, on which, if mosquito control by chemical means was attempted would raise the tax rate an additional $.17 per $100 assessed valuation or $140,000. This is the main reason we have been investigating the use of the mosquito fish, *Gambusia affinis* (Girard and Baird) in rice fields. Other stimuli are that the continued use of chemicals, where not absolutely needed, may bring criticism from an environmentally alert public, and that unnecessary spraying with chemicals will undoubtedly speed development of insecticide resistance.

To control the mosquitoes that might hatch from the rice field habitat and to prevent the "problems" cited above we commenced a research project in 1970 to assess the efficacy of mosquito fish (Hoy, O'Berg, and Kauffman, 1971).

In 1971, the project was enlarged approximately eight-fold and was also modified based upon conclusions drawn from the 1970 study.

[1]Sutter-Yuba Mosquito Abatement District, 925 Market Street, Yuba City, California 95991.

[2]United States Department of Agriculture, Entomology Research Division, 5544 Air Terminal Drive, Fresno, California 93727.

The new project was to have the test field divided into four categories. One, was to combine *Gambusia* at a rate of 0.2 lbs per acre (100 fish per acre) with a single early season application of Dursban® (chlorpyrifos) at a rate of .0125 lbs per acre, but due to an inadequate supply of fish we sprayed the Dursban and omitted the fish. The second treatment category was planted with 0.2 lbs per acre (100 fish per acre); the third category was planted with 0.6 lbs per acre (300 fish per acre); and the fourth category was used as an experimental control. The results of the project are reported by Hoy, O'Berg and Kauffman (1971).

The project was conducted by the U. S. Department of Agriculture, under the guidance of Dr. James Hoy, with the majority of men and equipment provided by the Sutter-Yuba MAD. The California National Guard provided and manned a large helicopter for fish planting.

There were not enough fish in local sites so we had to seek them in places out of our area. We obtained over 375 pounds of fish from a commerical bait dealer in Woodlake, California, near Visalia. A lesser amount was obtained from a similar source south of Sacramento, California. Nearly 330 pounds of fish were collected by District personnel from sewerage oxidation ponds near Angels Camp, California.

To collect and/or transport, as well as to prepare for planting from helicopter or pickup trucks, required a lot of equipment. On the trips to Woodlake we took a two-ton flatbed truck and a ¾-ton pickup truck. On the flatbed we had a 500 gallon stainless steel tank, a 200 gallon steel tank, and a 55 gallon steel drum. To provide oxygen to the fish in these containers we had both 110 and 12 volt agitators; to power these we had a 100 volt generator and two 12 volt batteries as a back-up system. We also took along one large bottle of compressed air as a supplementary form of aeration, and a portable 110 volt freezer to maintain an ice supply for water temperature control.

Additional equipment needed to get mosquito fish from the oxidation ponds near Angels Camp included a 12-foot aluminum boat, two live boxes, and 30-foot nylon seines, with 3/16 inch mesh. Several of the ponds were quite deep so the boat was used to get the seine out away from the shore. The live boxes were towed behind the boat and when a large number of fish were caught they were dumped into a live box. This allowed the fish to spread out and not be as crowded as in a seine. Since the bottom of the box was covered with ¼ inch hardware cloth, young fish and males were allowed to escape.

Traveling time to the study area was five hours from Woodlake and three from Angels Camp. Only from Angels Camp was there any significant mortality; the cause was never determined.

References Cited

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SOME ECOLOGICAL ASPECTS OF MALARIA IN CALIFORNIA

Stanley F. Bailey
University of California
Division of Natural Sciences–1, Santa Cruz, California 95060

It is always a challenge to try to piece together what actually happened in important historical events. Such is the case with the introduction of malaria into California and the subsequent devastating epidemic among the Indians. Usually considerable background reading is necessary in such cases and recently we have had the time to do this. In previous years our ecological study of anopheline mosquitoes gave us an understanding of the seasonal habits, distribution, and limitations of the vector species. We now bring this information to bear in an attempt to present what we believe to be a logical sequence of events that took place in 1830-33. Brief mention of malaria in the state following its introduction and in recent years complete our thoughts and observations on the subject.

There is no point in again reviewing the detailed accounts of Cook and Gray and Fontaine who have extensively researched the epidemic of 1832-33 in particular. We will begin with the knowledge that malaria was introduced to Fort Vancouver, across the Columbia River from Portland, Oregon in 1829, via infectives most probably on one or more ships (Stage and Gjullin 1935). Cook wrote "that the entire white population on the Columbia almost without exception suffered from malaria in a more or less acute form in 1830, 1831, and 1832.––Hence any person traveling by foot or horseback from the Columbia outposts to the California valleys had, it may be estimated, a nine out of ten chance of being a malaria carrier".

Understandably, the majority of trappers kept few if any logs of their excursions and some were lost, therefore, historians in attempting to reconstruct their travels show gaps and conflicts in dates. Work's expedition to California in 1832-33 (Maloney 1945) from the Hudson Bay Company at Fort Vancouver is by far the most important and we will come back to it in detail later. From the many writings covering this period (Cleland 1930, 1950; Gilbert 1879; Twitchell 1925; Sullivan 1934; Binns 1967; Maloney 1940, 1945; etc.) we find that three important trappers, Jedediah Smith, Peter Ogden, and Ewing Young traversed the Great Valley previous to partisan John Work's expedition. Their parties often numbered 60 or more, including many Indians. Smith had a base camp on the lower Stanislaus River and ranged as far north as the American River in 1826-27-28. Some of his party remained the entire summer of 1827 at "Wimilchi" in the central lower San Joaquin Valley. In the spring of 1828 he trapped near French Camp and north to Butte and Deer Creeks on the east side of the Sacramento River (Cleland 1930). Ogden (from Fort Vancouver) came up from Southern California in the spring of 1830 and trapped up the Sacramento Valley (with Young for about ten days) to the Pit River also camping at French Camp (Maloney 1940) along the way. Young trapped in the Delta region in 1830-31, also stopped at French Camp, returned from Los Angeles in 1832 and covered the lower American and Feather River beaver area, as well as Putah Creek on the west side of the Sacramento River (the Wintun Indian territory). He met Michel Laframboise of the Hudson Bay Company on the San Joaquin in the fall of 1832. McLeod, not as well known as a California trapper, established French Camp as an outpost of the Hudson Bay Company in 1828. Thus, up to the time of Work's camp on the Buttes in December-February, 1832-33, there were only two semi-permanent camps of note. Here the trapping parties remained long enough to establish continuing contact with the native Indians over a period of weeks (or months), presenting opportunity for successful malaria transmission. However, there are no recorded reports of sickness among the trappers or Indians in the valley during the period 1826-32.

It was the habit of the trappers to set out their traps, gather the catch the following day, stretch the pelts on willow hoops (Russell 1967) and move on. If the catch was very good and additional profitable trapping was indicated, such was done from a temporary base camp.

A more detailed examination of the log of Work further pinpoints, we believe, Yuba City as the "critical contact" area. After arriving in the Sacramento Valley in late 1832 the Work party traveled south to the Butte Sink and lower Feather River area by December 9, making camp in the Marysville Buttes. The local Southern Maidu Indians came to this camp December 11-20. The Laframboise trapping party from French Camp spent Christmas with Work in the Buttes and by December 29, they were almost completely surrounded by the flooding Sacramento River. The lower Feather and Bear Rivers and the Wheatland-Lincoln area south to Auburn Ravine and the American River were trapped up to January 16, 1833, and by the 22nd, both parties, totaling 163 people, were back at the Buttes Camp. (We believe this camp to have been in the vicinity of the present Fremont monument.) Hundreds of Indians had been seen in many villages in the entire area and they came in large numbers to the camp all winter, particularly to get meat when the hunters killed. During this period of encampment 395 elk, 148 deer, 17 bear and 8 antelope were killed. Again, by February 5, the Buttes were nearly surrounded by water. The ridge or contour along the old Butte House Road between Sutter and Yuba City usually makes east-west access possible during the flood periods. Undoubtedly it was along this route that both Indians and trappers traveled during this important period.

Members of John Work's party (about 100 people) both whites and Indians, had acquired malaria along the Columbia River before leaving for California (Cook 1955) on August 17, 1832. On their trip south during the fall members of the group continued to be ill with fever. Work noted on December 2, in the Deer Creek-Pine Creek area some sickness among the native Indians. Jed Smith had been here on April 5, 1828 (Sullivan 1934). Throughout the remainder of their expedition that winter and spring no other illness or epidemic among the Maidu or Wintun Indians was recorded. It was not until the following August, 1833, did Work see the shocking evidence of the epidemic in the Bear River-Butte Creek area villages on his return trip north. Somewhat further north (the Pine and Deer Creek area again) he observed the Indians to be in better health (August 17). Therefore, it appears the major focus of the initial infectives was in about a 65-mile stretch between the Bear River south of Yuba City and approximately Chico. In this area, below 1000 feet elevation which was the principal beaver trapping zone, there were 23 Indian villages (Kroeber 1925).

The trappers and their Nez Percés Indian helpers, in the winter, lived in leather lodges for protection from the elements. These "tepees" were made with poles and hides which they carried with them. The mosquito, ***Anopheles freeborni*** Aitken, readily enters any human or animal shelter, even through small openings. Its relative, ***Anopheles punctipennis*** Say, shuns covered or rather tightly closed shelters and will not pass through small openings. In addition to this winter camp at the Buttes, there were two other trappers' camps, as mentioned above, which were occupied for longer periods; the Jed Smith camp on the lower Stanislaus River and French Camp. In these areas, at least in the present century, large numbers of anopheline mosquitoes do not pass the winter. In contrast, in the Buttes, very large numbers of *A. freeborni* annually over-winter.

At this point perhaps it should be pointed out that the Indian houses in their permanent winter villages were excavated about three feet below ground, brush and reeds thrown over a pole framework and covered with the excavated dirt. The entrance was a narrow opening sloping downward. A hole in the top allowed the smoke to escape. The Indians slept on raised platforms made of poles covered with skins, reeds or feather blankets. The smoky interior often became so hot that sleeping was in the nude (Kroeber 1925). Several families occupied each house. The mosquito, *A. freeborni*, would have entered readily through the restricted door and even downward via the roof vent when no fire was burning. Along the lower portions of the walls and beneath the sleeping platforms ideal resting sites were to be found, providing the other conditions were tolerated. Obviously, there was ample opportunity to become blooded. In the larger villages a ceremonial or dance house was to be found. In these structures, not regularly heated, there were undoubtedly large numbers of over-wintering mosquitoes.

It can be seen that there must have been adequate opportunity for the Indians, having contacted Work's party on the Buttes, to have spread malaria in their villages in the Yuba City area during February and March. It is at this time that *A. freeborni* becomes very active and bites readily and insistently at all hours if the temperature is above about 55°F. Now to return to the highly significant details of the travels of the Work party. They left the Buttes camp on February 23, 1833 and trapped through Oroville to Chico, crossed to the west side of the Sacramento River for the first time, near Stony Creek. Their journey took them south to Williams (March 8) and down Cache Creek through the heavily populated Wintun Indian area to Woodland and Winters (March 12-16). No sickness was noted among these Indians which during the flood periods were isolated from the eastern Maidu tribe. Here it should be mentioned that Young's party had previously passed through the Putah-Cache Creek areas of Yolo County. The highly malarious group of Work reached Napa on April 9 and many again had chills. They proceeded to the coast and returned via Clear Lake, reaching Woodland on May 29. Again no mention was made of sickness in the local Indians. June and July were spent in the Delta and lower Consumnes, Mokelumne and Stanislaus River areas. Many mosquitoes were encountered during this period. On August 1, 1833, on their return north near the junction of the Bear and Feather Rivers south of Yuba City, many Indians were found "sick with fever". Near the Buttes, the villages were almost deserted and near Chico Creek (August 14) "the natives were even more sick". This north-south area, a distance of 50 to 60 miles, was the general vicinity of the major epidemic.

Further north near Deer Creek (August 17) the Indians were in better health. Between Cow and Hat Creek (August 21-29), 72 members of the Work party became very ill with "shaking fits". In this vicinity no sickness was observed in the Indians. This area was the territory of the Yana tribe which was very hostile. These Indians had little or no contact with the trappers and did not appear to have contracted the disease.

During the summer the Indians slept under open brush sun shelters along the banks of major streams lined with oaks, willows and cottonwoods. Such an environment was ideal for *Anopheles punctipennis* breeding. The seasonal peak of this mosquito is reached in May and June. Thus we believe that this vector was of major concern in transmitting the disease through the Maidu villages in the spring and early summer of 1833, some of the Indians having initially acquired it via *freeborni* in the late winter at Work's Butte camp. These Indians rarely traveled very far and had little or no contact with other sub-tribes such as the Wintun, Miwok, Pomo, or Yana (Kroeber 1925). However, very frightened and disconcerted by the many dead, large numbers of which remained unburied, the survivors entirely abandoned their villages, scattered, and were absorbed by other sub-tribes in the Sacramento and upper San Joaquin Valley. Thus the disease was spread throughout the Great Valley (Chamberlain and Wells 1879).

Another factor (aside from no immunity) that undoubtedly contributed to the unusually high Indian mortality, vs. the trappers, was the use of the "sweat house" when ill. Green wrote that "it was regarded as the never-failing remedy for the Indian whether his ailments were little or great and into it they went, whether afflicted with typhus or toothache, a fit of indigestion or the smallpox. There were doubtless cases, in which these hot air and cold water baths were beneficial and perhaps in many cases were not hurtful, but in cases of smallpox and other kindred diseases which sometimes swept over the country, as occurred in 1829, 1833 and 1856, the 'sweat house' panacea proved dreadfully fatal." Likewise to the north, it is interesting to note that Ogden (Binns 1967) wrote that in checking the Indian villages near Fort Vancouver about a month after he recovered from an attack he found all were dead. "The Indians had relied on their own method of treating a fever by plunging into cold water; and they had made death unanimous" (see also Chamberlain and Wells 1879). The trappers and white residents of Fort Vancouver did not suffer a high mortality, had quinine available, and, of course did not use the sweat house treatment. Twitchell did not consider this "supplementary" factor in doubting malaria as the cause of the great Indian mortality in 1833.

French Camp (near Stockton), a field base for the Hudson Bay Company, was established in 1828 and closed in 1845. All the trapping parties apparently stopped here at one time or another during the beaver-trapping era. Laframboise appears to have been the most frequent occupant. It should be noted that he came down the coast, via San Francisco, to this camp first in the fall of 1832, having come also with Columbia River Indians after the initial epidemic at Fort Vancouver, as did Work. He seems not to have kept a log and in one of the writings we have seen was there mention of sickness among the Indians of this vicinity. Since the notes kept by Work are so pertinent we refer to them again. His party trapped on the lower Consumnes and Mokelumne Rivers and stayed at French Camp and vicinity June 10-30, 1833. Indians visited their camps daily and brought berries for trade. Further, the log in several instances mentions the great mosquito nuisance. Work's party, with many infectives thus exposed this portion of the Miwok to malaria in June-July 1833. All conditions should have been favorable for transmission. However, there was no mention of any of the trappers having chills until August 13 near Chico on their return north. Also, an ecological item of importance was noted by us in Gilbert's History of San Joaquin County, namely, Lone Tree Creek on which French Camp was located was dry in summer.

In spite of the 1833 epidemic, Laframboise returned to central California to trap successfully in 1834, 1836, 1837, 1839, 1840 and 1842. In the winter of 1837-38 for example he had a temporary camp at the junction of the Feather and Sacramento Rivers at which he had accumulated 2700 skins. Apparently malaria was not sufficiently severe to preclude expeditions after 1833 (Cleland 1950).

Malaria during the Gold Rush has been covered in some detail by Fontaine and Gray. In reviewing some of the extensive writings of this historical period we have been particularly interested in some of the old photographs of the well-known mining districts of Placerville, Auburn, Grass Valley, etc. These prints showed the surrounding hills to be completely denuded and the surface of the ground a churned-up mass of rocky rubble. All shade along the streams was eliminated, the streams or portions thereof diverted for sluicing and the water thereby constantly muddied. Egenoff has assembled many such pictures and quotes from an 1857 publication of Borthwick as follows -- "the whole country had been ransacked, every flat and ravine had been prospected". Such a drastic alteration of the environment would have eliminated *A. punctipennis* in and about the larger communities. In contrast, in the open, sunny, grassy pockets, watered by overflows, seeps, waste sumps, etc., *A. freeborni* would have flourished. In recent years we have collected anophelines extensively in the Mother Lode area from Oroville, San Juan, Smartville, Pilot Hill, Diamond Springs, Volcano, Angels Camp to Columbia. All through this area *freeborni* is common and readily collected in such open, grassy, fresh water sites up to about the limit of the Digger pine. On the other hand, one has to seek out the very specific and widely scattered breeding sites of *punctipennis*. This vector mosquito uses its favorite niches year after year if they are not disrupted. Thus, in the helter-skelter, rough-and-ready type of life the miners lived in the Sierra foothills we believe *freeborni* was undoubtedly the principal malaria vector. In passing it is interesting to note that Egenhoff (1949) quotes from correspondence of the time that upwards of 4000 men were working in the American River gold district, more than half of which were Indians. Some of these Indians from the nearby villages were survivors of the 1833 epidemic and were undoubtedly carriers, in addition many newcomers from malarious areas of other countries. Today it is difficult to visualize the countless breeding sites for mosquitoes offered during the height of the hydraulic mining period. More than 6500 miles of ditches were built to carry water from the High Sierra to the mines below. Scores of dams were constructed. One ditch was 80 miles long. In the middle '80's, three mining companies near North Bloomfield used more than 100 million gallons of water daily in the giant nozzles (Wyckoff 1962).

Another ecological change that occurred during the early history of the state was the replacement of the great abundance of wild animals (as hosts of the mosquitoes) by introduced livestock. The peak of the cattle period according to Hutchison (1946) was 1850-1863 and 1870-1875 for sheep. Dasmann states that there were 3,000,000 cattle in the state in 1862 and by 1876 there were about 6,400,000 sheep (Hutchison 1946). Washino (1970) has recently presented data to illustrate the present-day source of blood of some of the most important mosquito species. Obviously we cannot know the original preference among the wild hosts and whether or not the shift to domestic animals was merely a matter of greater availability. Crop irrigation came into use about this time and by 1870 there were about 60,000 acres somewhat crudely irrigated at Cottonwood and near Wheatland. This change also gave *freeborni* the opportunity to increase greatly, and, adjacent manmade structures, ideal for over-wintering in place of scattered, natural winter shelters made it possible for large numbers of adult mosquitoes to pass the winter successfully. This aggressive vector was thus given every opportunity to transmit the disease to the rural population in the latter part of the century.

In addition to Cottonwood and Tehama, Penryn was a well-known malarious area. When the writer first began conducting field research with fruit pests in 1930, Harry E. Butler was still living at Penryn and we had an opportunity to learn the story of malaria and its control in Placer County (circa 1910-20) first hand. During the Depression years the foothill orchards were neglected, irrigation ditches became choked with grass, and the dominant *freeborni* increased markedly. Many years later, following World War II, when our field work was largely in mosquito ecology we became familiar with established local *punctipennis* "spots" along Auburn Ravine, as well as Secret Ravine and other minor streams in that County.

In a study of the seasonal history of the three anophelines found on the western slopes of the Sierras, Bailey and Baerg (1966) found that at low elevations (about 200-600 feet) *freeborni* is the species most often collected. It is found generally in farm ponds, reservoirs and sunlit, grassy ditches. Movement of *punctipennis* away from its very local breeding sites was negligible. At an elevation of about 1400 feet this latter species reached a seasonal peak in July (1965) while *freeborni* maintained its numbers at a lower level all season. High summer temperatures depress the *freeborni* population and biting is minimal in June and July. In this foothill district the winter concentration of adult *punctipennis* is much greater than *freeborni.* Washino and Bailey (1970) have reported that *punctipennis* shows nearly complete absence of blood feeding in November and December and that feeding increased in the latter part of February but to a much lesser extent than *freeborni.* We have collected blooded *freeborni* all winter at the margin of the Sacramento Valley (unpublished data) and Washino (1970) has shown its winter seasonal feeding pattern to be reduced. Lastly, an additional and very important difference in the winter habits of the two species in Northern California should be emphasized. During the winter there is a continual relocation of adult female *freeborni* from place to place, often many miles from the late summer collecting sites (Bailey and Baerg 1967). In sharp contrast *punctipennis* remains quiescent in resting sites nearly always close to the breeding area, and often in a flattened position not moving for days at a time. These differing characteristics of the two species are pointed out because of their important bearing on the famous epidemic of 1833 and what we believe was the part each species played in the transmission of malaria to the Indians from the trappers. We believe *A. freeborni* to have been the vector at John Work's camp at the Buttes in the winter of 1832-33 and *punctipennis* the principal vector in the Maidu Indian villages on the east side of the Sacramento River in the spring and summer of 1833. During the Gold Rush both species undoubtedly were involved but *freeborni* probably to the greater degree.

Miner local epidemics of malaria occurred near Lodi in 1934-35 and near Winters in 1938. Gray and Fontaine (1957) described briefly the conditions. The shaded campgrounds of the agricultural migrants along the Mokelumne River presented an ideal *punctipennis*-type breeding locale. Sleeping in the open was the rule and the environment was strikingly similar to that found by the trappers in the Indian villages along nearly all the major streams entering the Great Valley one hundred years earlier. The Winters epidemic, also in the immediate vicinity of the Indian villages seen by Young and Work in 1832-33 on Putah Creek, was among the farm workers in a recently constructed Government Labor Camp. This camp was a short distance north of Putah Creek and surrounded on three sides by orchards. The writer lived only a few miles to the east and was very familiar with the farming area and its residents. To the north of the camp were irrigated field crops such as alfalfa, sugar beets, beans, and a small rice acreage. One of the local farmers residing about two miles to the northeast of the camp contracted the disease. His farm was located in an open, flat area. While *punctipennis* was the likely vector a hundred years earlier when the area was wooded, in this case, *freeborni* most certainly was the carrier. The only other anopheline in the vicinity is *Anopheles pseudopuntipennis franciscanus* McCraken, a non-vector.

In the Lake Vera Campfire Girls Camp epidemic of 1952 (Fontaine et al. 1954) no extensive larval collections (rearings) or population counts were made at the time. Both *freeborni* and *punctipennis* were collected late in summer by the writer and R. M. Bohart. However, in 1967, R. K. Washino and the writer found larvae readily at this location (about 2400 feet). Adult rearings produced 76 percent *punctipennis* and 24 percent *freeborni*. This percentage was almost exactly the same as found from extensive collections and rearings made from an established farm pond at 1400 feet elevation, also in Nevada County (unpublished data). At these Campfire Girls camps on the lake practically no mosquito control was done and, surprisingly, camp personnel interviewed had little or no knowledge of the 1952 epidemic. In other words, all conditions were present for favorable transmission should an individual with an active case of malaria again come into the camping area.

In recent years the number of recorded cases of malaria in California has increased greatly, due almost entirely to recurrent attacks in veterans returning from Vietnam. John R. Walker of the Bureau of Vector Control, State Department of Public Health, has supplied us with the tabulation which clearly illustrates the trends during both the Korean and current conflict. (Table 1.)

These relapses are scattered throughout the state but the majority occur in metropolitan areas or localities lacking active mosquito vectors. Minimal opportunity therefore is presented for the inception of an epidemic. However, an increasing number of people are acquiring the disease via transfusion with commerical blood. Further, as a "sign of the times", a few cases have been acquired from unsterilized hypodermic needles!

It seems to be a characteristic of man--white man in particular--that wherever he goes he alters the environment. He clears the land, drains swamps, impounds water, and digs up the minerals thereby destroying wild plants and animals. He uses up the natural resources to his material advantage and creates for himself an artifical environment. Students of Indian lore believe the California tribes had lived here for more than 5,000 years, largely undisturbed, and in balance with their environment. The early coastal explorers and the

Table 1.–Reported cases of Malaria in California 1950-70.

YEAR	TOTAL	CIVILIAN	MILITARY
1950	18	14	4
1951	258	33	225
1952	926	173	753
1953	429	95	334
1954	69	41	28
1955	132	33	99
1956	61	51	10
1957	40	32	8
1958	24	16	8
1959	25	20	5
1960	10	9	1
1961	14	10	4
1962	9	6	3
1963	25	19	6
1964	16	12	4
1965	42	16	26
1966	108	22	86
1967	223	28	195
1968	376	27	349
1969	564	28	536
1970	429	36	393

Padres[1] caused no change in the interior. The trappers were on the move most of the time and usually killed game only to eat. They did, however, alter the environment indirectly in a small way. They removed many beaver that impounded streams in the foothills and when the spring snow-melt and high water washed out the beaver dams they were not always repaired. The shoreline thus was changed and some breeding areas of mosquitoes were altered. During the 1830-50 period very little local clearing of the land was done and early grain farming was mostly in open, hilly districts. Following the discovery of gold, 1850 to 1880, drastic changes occurred. Up to about 3,000 feet on the western slope of the Sierras all the streams were mined and the general environment greatly altered as mentioned above.

The population increased very rapidly the latter third of the century and settlements began to spring up throughout the Valley. Many discouraged gold seekers found other occupations and a good number turned to farming as the land was more or less "free". Land clearing increased and somewhat crude irrigation systems were established near the end of the century. Malaria then became much more concentrated in such valley communities as Marysville, Tehama and Anderson and former mining locales as San Juan, Penryn, etc. We have described malaria in California in the present century briefly and more extensive treatments of the subject can be found in the terminal references. Anthropologists, sociologists, and geographers have studied the changes that civilization brings about in native tribes. It is generally known that when "civilization" moves in it brings new diseases, changes in diet, clothes, and housing and the natives, having a lower or primitive way of living, perish as a result of these "cultural" changes.

Today another change in the former malarious area is taking place--on a small scale. Foothill living is becoming popular and along with it lakes, ponds, and reservoirs are being widley established. Man feels the need to be "near the water" for living and recreation. Summer camps, second homes, golf courses, retirement communities, commerical trout ponds, etc. all have increased again the potential for the increase of local foci of *punctipennis*, as well as for *freeborni*, in the lower foothills from about 200-2,000 feet.

Presently in the rice-growing districts of the Great Valley, where *freeborni* maintains itself in large numbers, we have the condition known as "anophelism without malaria". With the need to conserve water more carefully in the future, we can expect to see more closed irrigation systems. The Valley agricultural towns will grow, land will become even more valuable and diverted to other uses, undoubtedly reducing the irrigated acreage. The density of *freeborni* thus will become reduced proportionately.

In Africa the conditions that confront malaria control workers have been described by Hall (1961). On this continent *Anopheles gambiae*, a highly efficient vector, carries *falciparum* malaria to hundreds of thousands of people each year. Here are found "unstable political situations, long seasons of transmission, sometimes extending throughout the year; labor migrations; wide dispersal of habitations in jungle war; lack of roads and other facilities to enable transportation and communication; nomadism, poverty and illiteracy; and lack of trained professional and administrative personnel to give necessary direction to the programs." In contrast, California has about as widely divergent conditions as are imaginable: distinct change in seasons with a long, dry summer, quite stable economic and political conditions (by comparison), a superior communication system, the know-how, personnel and equipment to quickly suppress potential epidemics. The transmission of malaria by mosquitoes among rural residents of this country is generally considered to be a thing of the past. However, the possibility of reintroduction still exists while the disease is present elsewhere in the world. Transmission of the disease via "contaminated commerical" blood by transfusion and by unsterilized hypodermic needles are beyond the province of ecologically-oriented entomologists!

In summary, it can be seen how ecological conditions have influenced directly or indirectly the history of malaria in California. The living habits of the Indians and the presence of two native anopheline vectors made transmission of the disease easily possible once it was introduced. The changes and disruptions in the natural environment wrought by the white man resulted in marked fluctuations in the relative abundance of the mosquitoes in the mining and farming areas. More recently the great changes in our living standards have all but eliminated the disease. Today there is little fear of endemic malaria as it competes very poorly with our modern way of life.

[1]No malaria was known in the Spanish Missions. Thos. H. G. Aitken, Univ. Calif. Publ. in Entom. 7:325, 1945, wrote "The sexual phase of the *Plasmodium* requires for its completion a temperature of 61°F (16°C) or above. The summer isotherm of 60°F cuts off the greater part of the California coast from about San Luis Obispo northward."

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SEASONAL DISTRIBUTION AND BEHAVIOR OF CALIFORNIA ANOPHELINE MOSQUITOES

Stanley F. Bailey[1], D. C. Baerg[2] and H. A. Cristensen[2]

For many years biological and ecological studies of malaria mosquitoes by entomologists were of a field research nature, by necessity, as a part of and tied to control. The initial period of problem solving was led by works of Freeborn (1921, 1926), Bradley and King (1941), Aitken (1945), Markos (1950) and many others. This was followed by a great proliferation of information in various basic phases of mosquito bionomics, including physiology, genetics, photoperiodicity, and communication, much of which has been financed by grants and other special funds. This report brings together detailed field and laboratory observations gathered at the University of California at Davis as a part of general ecological investigations of the four species of California anophelines: *Anopheles punctipennis* Say, *A. franciscanus* McCracken, *A. freeborni* Aitken, and *A. occidentalis* Dyar and Knab.

[1]University of California, Division of Natural Sciences–1, Santa Cruz, California 95060.

[2]Gorgas Memorial Laboratory, Box 2016, Balboa Heights, Canal Zone.

STUDY AREA AND METHODS.–The main area under investigation was a transect of northern California from the Sierra Nevada Mountains at Emigrant Gap to the Pacific Ocean at Point Reyes Station (Bailey and Baerg 1966). Supplemental surveys were taken from the Oregon border south to Pismo Beach, and from the northeastern portion of the State and the desert area to the southeast.

It was difficult to locate comparable semi-permanent breeding sites throughout the transect largely because of pollution by cattle, variable and unpredictable flushing by spring rains and irrigation practices. In the Sacramento Valley proper it was rare to find any natural, undisturbed breeding areas. No larvae of *A. punctipennis* were found on the floor of the Valley. Nearly all stream beds had been filled, diverted, or modified for irrigation or flood control purposes. As a result, *A. franciscanus*, also once common in the Valley, was found primarily in the peripheral foothills. As seasonal pools dried, particularly on the west side which lacks the snowmelt water seepage of the eastern slope, it was necessary to shift our collecting sites to those still producing larvae.

Immatures obtained in collections were laboratory-reared to adults to enable positive identifications. Adult mosquitoes were aspirated from resting stations and their physiological condition determined visually. Individuals that were classified as "with blood" were wholly or partially engorged or had a portion of the blood meal digested with eggs apparent. Christopher's stage of follicle development was determined only in the case of *occidentalis*. Many hundreds of adult and larval samples were taken year-round in almost every conceivable place of resting or breeding. Two species, *franciscanus* and *occidentalis*, were studied in detail for doctoral theses (Baerg 1967; Christensen 1968).

Laboratory colonies of *A. freeborni* and *franciscanus* were maintained for several years, and *occidentalis* was colonized for several generations. The southern strain of *occidentalis*, commonly referred to as "*freeborni*" by various writers, was maintained in laboratory culture for over one year. Attempts to establish a breeding colony of *punctipennis* consistently failed, although the species was collected regularly throughout the program. It is noted, however, that laboratory colonization of eastern strains of *punctipennis* have been successful (Boyd and Mulrennan 1934; Dr. Martin D. Young, personal communication).

DISTRIBUTION.–Each of the four species presents a distinct dispersal picture which is best described ecologically. Various writers (Herms 1921; Aitken 1945; Freeborn 1949; Markos 1950; Freeborn and Bohart 1951; Loomis et al. 1956) have given many details on the distribution and exact type of environment in which each species is found. This information need not be repeated here.

Our extensive series of collections of the aquatic stages of these anophelines are given in Table 1. The tabular data summarize a total of 412 collections at 219 stations from 1964 to 1967. New findings of interest might be mentioned. Larval populations were sampled extensively along the northeastern border of the state in 1966, which is the western edge of the Great American Basin. *A. franciscanus* was found in Lassen and Plumas counties. At the other extreme, this species was taken near the Salton Sea at -200 feet elevation. In 1967 the breeding of *occidentalis* in Del Norte County at Crescent City and at Pismo Beach, San Luis Obispo County, was verified. In the pine belt, above 4,000 feet, anophelines are very rarely collected. In open sagebrush-juniper areas, however, *franciscanus* was found in receding streams up to 5,200 feet.

Table 1.–Summary of *Anopheles* Larval Collections. North-Central California. 1964-67.

Area	Species	Number stations species occurred	Relative frequency of species collection
East of	*franciscanus*	21	52
Sacramento	*freeborni*	53	98
River	*occidentalis*	0	0
(72 Stations)	*punctipennis*	34	83
West of	*franciscanus*	27	51
Sacramento	*freeborni*	13	15
River	*occidentalis*	0	0
(38 Stations)	*punctipennis*	12	55
Coastal	*franciscanus*	51	88
watershed	*freeborni*	13	31
	occidentalis	41	104
(109 Stations)	*punctipennis*	53	123
TOTALS	*franciscanus*	99	191
	freeborni	79	144
	occidentalis	41	104
(219 Stations)	*punctipennis*	99	261

We have recorded previously the finding of an "overlap area" near Napa where *occidentalis* and *freeborni* were present. Near and southwest of Healdsburg in grassy side pools along the Russian River during 1965-67 we found these species. *A. freeborni* was collected at Monte Rio five airline miles from the ocean and *occidentalis* was obtained five miles south of Healdsburg, which is the greatest distance inland for this anopheline. During World War II, in April, 1944, the senior author collected and reared *freeborni* taken from a grassy fresh water seepage pool in the former U. S. Marine Base dairy barn at Mare Island Navy Yard. This site was not along the ocean proper, but was less than 100 yards from San Pablo Bay.

No new or unusual records of *punctipennis* were gathered. As this species is very specific in its habitat, it is nearly always possible to anticipate the finding of the larvae by recognizing the proper ecological conditions. These niches, however, are entirely absent in such areas as desert regions, alkaline marshes, polluted farm ponds, and snow fields. Even when what appears to be an ideal environment is found, at moderate to high elevations in the Sierra Nevada Mountains none have been collected by us. Carpenter (1969) obtained *freeborni* at 6,000 feet in Sierra County. Aitken's record of *franciscanus* in Alpine County (7,300 feet) still remains unique.

SEASONAL INCIDENCE.–The relative abundance of anophelines varies from year to year and locality to locality. Several important factors, including the total rainfall and its distribution, the spring and summer maximum and mean temperatures, and the type and acreage of irrigated crops and economic conditions directly or indirectly influence seasonal fluctuations. Our observations in two contrasting ecological areas in northern California, the coastal belt and the Sierra foothills, clearly illustrate a predictable pattern of appearance and abundance of the four anophelines.

These stations were not sampled regularly each season, therefore, direct comparison of the population densities of the anophelines in the same year is not available.

On the coast at Pt. Reyes Station, 22 larval collections were made between January 7 and December 30 of 1966. The data gathered from an established farm pond, a ditch and a small swamp were as follows:

	Seasonal Range of Larvae	Total No. Collected
A. franciscanus	Jun. 21–Oct. 29	185
A. occidentalis	Mar. 22–Nov. 12	1,530
A. punctipennis	Mar. 22–Nov. 12	364

Table 2.–Summary of abundance and seasonal feeding activity of *Anophelines* in resting stations at Pt. Reyes Station, Calif.

	franciscanus		*occidentalis*		*punctipennis*	
MONTH	no. females collected	percent blood-engorged or gravid	no. females collected	percent blood-engorged or gravid	no. females collected	percent blood-engorged or gravid
1966						
April	0		1	0	10	10
May	0		2	100	3	100
June	1	100	124	37	16	81
July	2	50	96	91	15	40
August	3	100	126	69	1	0
September	1	100	82	51	7	14
October	2	0	52	26	16	6
November	1	0	23	0	17	0
December	0		45	9	36	0
1967						
January	0		14	29	9	22
February	0		1	100	5	0
March	0		0		0	
TOTALS	10	0-100	566	0-100	135	0-100

From the same locations, in abandoned buildings and a culvert, 23 adult collections were taken over a two-year period, 1966-67 (Table 2). During the summer in this cool coastal climate *franciscanus* persists only marginally, *punctipennis* is common and widespread, *freeborni* does not occur and, as is obvious by the above data, *occidentalis* is the most abundant species. As *punctipennis* does not congregate in protected stations until the colder, rainy season begins, this species actually may be more numerous before this time.

During 1965, 19 visits were made to the foothill study area, Wolf Creek, from March 30 to December 16. A tabular summary of larvae from a sunlit, established farm pond (1,314 feet elevation) and its shaded seepage ditch is given below.

	Seasonal Range of Larvae	Total No. Collected
A. franciscanus	Jul. 1–Nov. 19	518
A. freeborni	Mar. 30–Nov. 19	299
A. punctipennis	Mar. 30–Dec. 2	1,393

Samples of adult anophelines taken from farm buildings in this area during 1965, and less frequently 1966-67, are shown in Table 3. These data illustrate two generalizations. First, in a brushy, rocky hill area the innumerable resting sites result in dispersal of the adults. Thus, manmade structures under these conditions give much lower adult counts in relation to the larval density. Secondly, in this area, which is a preferred breeding area for *punctipennis* (note larval density), the adults did not congregate in buildings but were scattered in shady thickets adjacent to the pond.

The above findings contrast with results of our collections from a barn near a long established local breeding area west of Vacaville. The latter station served as an ideal resting site of *punctipennis*. No breeding of *freeborni* occurred in the area.

It is interesting to compare the figures obtained by Herms (1919) in California's first mosquito survey in 1916-17. In the Sierra counties he found that *freeborni* comprised 16%, *punctipennis* 67%, and *franciscanus* 17%. In the Sacramento Valley counties his collections totaled 82% *freeborni*, 7% *punctipennis*, and 11% *franciscanus*. Our data on anophelines sampled from the Nevada County study area in 1965-66 produced strikingly similar figures; 14% *freeborni*, 63% *punctipennis*, and 23% *franciscanus*. In the Capay Valley on the west side of the Sacramento Valley proper (Table 4) our 1964-65 adult collections, in sufficiently large numbers to give good reliability, gave 92% *freeborni*, 6% *franciscanus*, and 2% *punctipennis*. Conditions in the farming areas have changed much more drastically in the past 50 years than those in the foothills. Nevertheless, the comparison demonstrates that the reproductive potential of these species has changed little in undisturbed areas.

Other series of collections show a different relationship. In the course of extensive flight range studies of *Culex tarsalis* (Bailey et al. 1965), CO_2 traps were employed in the Sacramento Valley, primarily in rice fields. These traps, in 37 experiments, caught 475,408 *tarsalis*, 18,502 *freeborni* (including one male), three *franciscanus* and no *punctipennis*. Anophelines are not attracted readily to this type of trap, as are *Culex*, but the numbers captured are an excellent index of the relative number in flight in a major agricultural area.

HOST PREFERENCE AND BITING ACTIVITY.–In most cases, the proximity, availability, and relative abundance of several acceptable warm-blooded hosts appear to determine the so-called host-preference. Mosquito blood-feeding patterns in California have been investigated by Reeves, Tempelis and Washino (1964, 1967). They found that man is not a common host. Rabbits, horses and cows rank at the top of the list of mammals, with other domestic mammals as well

Table 3.—Adult Anopheline collections and seasonal feeding activity in resting stations at Wolf Creek Ranch, Nevada County, California. 1965-67.

	franciscanus		*freeborni*		*punctipennis*	
	number females	percent blood-engorged	number females	percent blood-engorged	number females	percent blood-engorged
1965						
May 4	0		0		0	
18	0		0		0	
June 3	0		0		0	
15	0		0		0	
July 1	1	0	2	100	4	100
15	5	33	0		1	0
27	11	33	0		0	
Aug. 10	13	100[a]	1	100	1	100
24	22	63	5	66	1	0
Sept. 9	12	0	0		4	100
21	14	29	1	0	0	
Oct. 5	12	0	3	67	0	
19	5	100	25	13	4	0
Nov. 4	4	0	24	55	5	0
19	2	0	lost		13	0
Dec. 2	4	0	55	0	13	0
1966						
Jan. 13	0	46	46	0	7	0
Feb. 10	0	23	23	9	2	0
Apr. 28	0	6	6	100	5	80
May 26	1	5	5	100[a]	0	
Oct. 26	10	58	58	19	10	0
Nov. 16	6	58	58	7	4	0
30	3	73	73	1	10	0
Dec. 14	0	65	65	0	7	0
1967						
Jan. 16	0	41	41	15	5	0
Nov. 8	0	8	8	100	5	100
TOTALS(males)	125(70)	0-100	499(10)	0-100	101(6)	0-100

[a]Includes gravid specimens.

as rodents making up the total tested, chiefly by the precipitin method.

In the field we have been bitten by all species with the exception of *occidentalis;* this anopheline readily feeds upon man under laboratory conditions. *A. freeborni* and *punctipennis* will bite during daylight hours, and the former is the only one to invade residences and bite indoors. *A. punctipennis* will seek blood in open sheds, barns and at the mouths of caves or old mine shafts. Along the coastal region, where three species of anophelines occur commonly, many residents were interviewed and none complained of mosquitoes (the salt marsh *Aedes* excepted).

Certain observations can be made from blood-feeding data in our samples (Tables 2-4). November and December normally are the months of minimal feeding, and no *punctipennis* with blood were seen during this period. During the winter in the coastal area, blood-engorgement was most consistent in *occidentalis. A. occidentalis* also showed egg development every month except April and November. Unfortunately the very sparse population of *franciscanus* found on the coast makes it difficult to draw a comparison with populations of the species in the other study areas. On the west side of the Sacramento Valley, blood-engorged *franciscanus* specimens were collected each month. Resting stations with a high percentage of immigrant adult *freeborni* (Capay Valley) exhibited a much lower ratio of blood-fed specimens than those harboring a strictly local population (Wolf Creek). Because of its aggressive and migratory habits, *freeborni* is the only anopheline in California considered as a pest mosquito.

The fall transition in *freeborni* feeding behavior is very dramatic. For example, in warm weather on September 28, 1965 near east Nicolaus, Sutter County, in the heart of a

Table 4.–Adult Anopheline collections and seasonal feeding activity in resting stations at Capay Valley, Yolo County, California[a]. 1964-65.

	franciscanus		*freeborni*		*punctipennis*	
date	percent number females	percent blood-engorged or gravid	number females	percent blood-engorged or gravid	number females	percent blood-engorged or gravid
1964						
May 28	1	100	0		1	0
June 8	0		0		6	0
23	4	75	0		1	0
July 16	3	66	0		1	0
29	24	62	1	0	0	
Aug. 11	31	75	0		4	0
25	12	81	46	35	0	
Sept. 1	1		147	9	0	
11	9	20	485	1	0	
15	12	33	520	2	0	
22	14	40	615	1	0	
29	24	38	837	4	1	0
Oct. 6	28	65	404	15	3	66
13	11	57	269	9	2	0
20	12	55	186	6	1	0
27	55	46	306	8	3	0
Nov. 3	34	28	413	6	16	0
10	28	12	310	9	26	0
17	18	0	213	2	15	0
24	10	0	2 155	1	6	0
Dec. 1	19	0	181	4	18	0
8	13	22	133	3	9	0
15	20	20	154	8	13	0
29	11	0	234	8	14	0
1965						
Jan. 5	9	22	68	6	5	0
12	7	0	91	4	5	0
19	10	0	114	15	3	0
26	8	14	72	6	2	0
Feb. 4	5	0	59	9	6	0
11	4	25	60	18	4	25
18	4	50	63	38	2	50
25	2	50	40	80	1	100
Mar. 4	2	0	8	50	2	100
11	3	66	7	43	0	
18	2	50	0		0	
TOTALS	450	0-100	6,191	0-80	170	0-100

[a]Five to 19 stations were collected each date, depending on accessibility. Data tabulated from stations collected ten or more times during study period.

rice growing area, 3,000 *freeborni* were collected from under a small bridge. These mosquitoes did not attempt to feed upon us in the field, and only 90 (3 percent) took a blood-meal in the laboratory. In the fall of each year large numbers of *freeborni* congregate under an abandoned bridge over the Sutter Bypass, in the center of the Sacramento Valley on the southwest side of the Marysville Buttes. During late September, October and early November we have estimated over 100,000 adults resting at one time under this structure, and of the many thousands collected only a very small number attempted to take blood. It is interesting to note that no other anophelines were seen here.

FLIGHT HABITS.–During the breeding season anophelines appear to disperse very short distances from the emergence sites. If hosts are in close proximity, the flight range need be but a few hundred yards or less. As the winter season approaches, preceded by a physiological interruption in egg production, the flight range of females is extended. At this time sheltered niches offering greater protection than the summer resting are sought. *A. punctipennis* and *occidentalis* congregate in shelters adjacent to the breeding locales, while *franciscanus* disperses into shelters often a mile from known summer larvae sites. The migratory species, *freeborni*, is the only anopheline that can be found in significant numbers remote from breeding sites. Flights into these winter hibernating areas, such as Capay Valley (Table 4) and the foothills bordering the Sacramento Valley (Table 5), can be observed in the same stations from year to year.

A. freeborni was studied in detail by us for four years (Bailey and Baerg 1967). We conducted 18 release-recapture experiments with marked mosquitoes totaling 54,800 wild-caught specimens with a 0.032% recovery. Following the releases, 89,685 unmarked and 328 marked specimens were collected at preselected stations. Some of the most important findings were as follows:

"Flights as far as 17.5 miles do occur on the part of some individuals; however, we feel the great majority of mosquitoes seek, and do find adequate overwintering quarters within five miles of their breeding site in most farming areas."

The mean distance from the release point for 18 recaptured marked mosquitoes was 3.05 miles. Large numbers of marked mosquitoes (310) did not leave the release site or its immediate vicinity.

The majority of marked specimens were recaptured in the rice growing area during October; at the release sites only during cold weather in December, and again in much smaller numbers after the middle of January during the spring movement.

Movement of the "prehibernation" population into the foothills at the margins of the valley definitely takes place up to at least ten miles, and abundantly up to 400 feet elevation (see Table 5).

During the winter there is a continual "relocation" of the semidormant females, with the exception of periods when the temperature is below 45°F.

The female of this mosquito (*freeborni*) commonly lives five months in the winter and occupies many different resting sites, often many miles from its point of origin.

OVERWINTERING.–In recent years a great deal of laboratory experimental work has been conducted on photoperiodicity in relation to the physiological cycles and dormancy in insects. Beck (1968), and more recently Washino (1970),

Table 5.–Distribution of Anophelines in relation to altitude in North-Central California 1963-64.

A. State Highway 20, West. Colusa-Lake Co. 10/1 - 3/19.

Elevation (feet)	Number adult females in resting stations.		
	franciscanus	*freeborni*	*punctipennis*
335	37[a]	1,187[a]	0
380	18	369[a]	0
640	22	108	0
790	9	57	0
817	3	24	0
1,016	34	335	1
1,055	1	5	0
1,135	20	29	0
1,725	307	35	0
TOTALS	451	2,149	1

B. State Highway 20, East. Yuba-Nevada Co. 9/11 - 1/30.

Elevation (feet)	*franciscanus*	*freeborni*	*punctipennis*
268	2[a]	327[a]	11
297	0	623[a]	8
395	3[a]	466[a]	13
683	0	220	7
1,300	0	16	32
1,451	0	56	12
2,040	0	1	3
2,640	0	2	0
TOTALS	5	1,711	86

[a]Includes male specimens (limited numbers observed and collected only in early fall).

Table 6.–Life span of caged, hibernating female *Anophelines* in natural resting stations November-March, 1966-67. (Percent surviving, with sugar and water).

Holding period (weeks)	*franciscanus* 80 females	*freeborni* 80 females	*occidentalis*[a] 25 females	*punctipennis* 80 females
1	95	69		89
2	74	47	100	85
3	41	34		81
4	22	19	96	72
5	6	12		60
6	4	10	56	45
7	4	7		31
8	1	6		20
9	1	5	24	12
10	1	2		9
11	0	2	12	7
12		2		6
13		2	12	6
14		2		6
15		2	0	6
16		2		5
17		2		1
18		2		0
19		1		
20		0		

[a]Laboratory-reared and tested in Point Reyes Station, October, 1967. Minimum temperature approximately 33°F. Other three species tested in Davis at a temperature range of 38-62°F.

have reviewed the highlights of the subject, the latter particularly in relation to mosquitoes.

Several types of conditions appear to affect (or determine) the nature and composition of overwintering populations of the California anopheline mosquitoes. The first is characterized by *punctipennis*, in which the adults usually originate from very localized and somewhat isolated breeding females, therefore, are rather uniformly aged individuals resulting from the normal, late summer generations. In the seasonal study of the farm pond in the Sierra foothills, two periods of abundance were observed for *punctipennis* larvae, with maximum numbers collected on July 15 and October 19. The latter produced adults that entered directly into hibernation.

In a study by Washino and Bailey (1970) it was found that *punctipennis* normally overwintered as inseminated females which did not take blood-meals, and developed fat bodies during September through December. Individual variation may produce occasional non-conformity as evidenced by one gravid female collected October 5, 1964, that laid 290 eggs in the laboratory in the first week, and another collected November 22, 1964, that produced 80 eggs after 11 days.

Weather conditions such as heavy late spring rainfall may be detrimental to the larval population by flushing out stream pools. Under these conditions diapausing females must arise from a population made up largely of individuals hatching from the early fall brood.

A mixed population of *occidentalis* occurred in the fall of 1967. In the other years, if the seasonal larval peak is well defined and is reached in mid-summer a high percentage of the fall adult population does not enter diapause but continues to reproduce. With the exception of 1967, blood-engorged or gravid *occidentalis* females were found from May through February.

A. freeborni are distributed throughout a wide range in latitude from Boundry County, Idaho (45.5°N. lat.) to El Paso, Texas (32°N. lat.). In the southeastern segment, cold winters undoubtedly have a great influence on the cessation of its egg development. However, this species is markedly influenced by the shortened daylight hours of late summer (Depner and Harwood 1966). Each year the majority of *freeborni* females comprising the overwintering population exhibit gonotrophic dissociation in California (Washino 1970). The artificial breeding area of thousands of acres of rice fields in the Sacramento Valley is generally infested with *freeborni.* Bailey and Gieke (1968) and others have shown that a peak of larval density is reached in late August through early September. The fields are drained abruptly, usually beginning early in September and continuing into October. On September 12, 1967, at Grimes (Colusa County) 93% of the larvae collected from two rice fields and a seepage ditch were first and second instars, suggesting that large numbers of mosquitoes might be produced during short daylight hours under special circumstances, i.e., in extensive and undisturbed ponded areas and late maturing rice fields (see also Sherman and Kramer 1970). During drainage of rice fields the larvae are flushed out into ditches and sloughs or are stranded in the muddy fields before completing development. However, many do survive, and the resulting adults are of nearly the same age.

The sampling of *freeborni* in the Capay Valley, Yolo County, showed blood-engorged females comprise anywhere from less than 1 to 15% of the population during the period of fall movement. In contrast, an isolated breeding population in the Sierra foothill pond produced 15 to 55% blood-engorged females from October 5 to November 4 in adjacent resting stations. There were three *freeborni* larval abundance peaks in this pond during the breeding season; June 3, July 27, and September 21. These examples illustrate the tendency in the species for some individuals to take blood during the fall (the extent depending on local conditions) and to physiologically divert the acquired energy away from egg development.

Only a very small percentage of the many thousands of wild *freeborni* adults collected in the winter months laid eggs within a few days after being brought into the laboratory. Many individuals developed eggs 4-10 days after taking a blood-meal, but withheld them until induced to oviposit by removal of their wings. We find a specific example in our notes of a gravid female taken about ten miles west of Davis on January 1, 1965 that laid immediately when brought into the laboratory. These experiences, obtained as a by-product of handling large numbers of wild adult *freeborni* (150,000), are cited to support the conclusions of Washino (1970) who stated "the overwhelming majority of females in September that enter diapause were nulliparous. . . No further ovary development was observed until diapause was terminated . . . there was no evidence that any single factor was responsible for termination of diapause."

We have found gravid females and early instar larvae of *franciscanus* in December at Mecca, in Riverside County (33.5°N. lat.). Other investigators also have reported this anopheline breeding in some part of California throughout the year, indicating that overwintering specimens are in a quiescent state rather than a true diapause. Washino and Bailey (1970) stated that blood-engorged *franciscanus*, in a few instances only, do not develop eggs in the fall and early winter in the Davis area. In the northern portion of the state breeding as well as feeding in this species normally ceases in cold weather.

In the Sierra foothills and along the central coastline, *franciscanus* larvae are the last of the anophelines to appear in the spring. In 1965 in Nevada County the first larvae were found July 1 and in 1966 at Pt. Reyes Station, on June 21. The larval populations increased to a maximum density in late August and persisted at a high level well into September; September 21 at the first above mentioned site and August 30 at the coastal site. Since there usually are not distinct broods, as in *punctipennis*, adults of various ages and physiological condition probably enter the winter quiescent phase with the onset of cold weather. There is a limited surviving adult population to initiate breeding in the spring. The cool water is less favorable to larval development of *franciscanus* than for other California anophelines.

The foregoing data illustrate some of the difficulties involved in attempting to categorize the types of dormancy exhibited by these species. While the unique record of a "last" larva in the fall or a "first" in the spring is not significant in itself, it is an indication that some individuals of a species population have an inherent capacity to be active and to survive extreme conditions within its range, although at times in precariously small numbers.

FACTORS INFLUENCING ADULT AND LARVAL POPULATIONS.–Temperature, the extremes and the average maximum and minimum, can limit the distribution as well as seasonal abundance of virtually all mosquitoes. One anopheline, *punctipennis*, is widespread in North America, but seeks larval breeding niches providing a cool environment. Many areas in which it occurs normally have a low winter minimum. However, the shelters used for hibernation, whether natural or manmade, would have a somewhat higher temperature than more exposed areas. We have collected females of all four species at readings in the low 30's; in such instances, the mosquitoes were reluctant to fly and often were flattened close to the particular resting surfaces. They all seek locations protected from the wind, thus minimizing desiccation. In the mountainous counties of Plumas, Shasta, Siskiyou, and Trinity, *franciscanus*, *freeborni* and *punctipennis* were collected. These areas have low winter temperatures. Since *occidentalis* is found only along the coast, it is not known whether the adults could withstand ambient temperatures close to freezing.

Limited experimental work has been conducted by us on this environmental factor. At a constant 43°F adult *franciscanus* and *punctipennis* survived five weeks--as indicated by normal activity when they were returned to room temperature. *Freeborni* lived nearly twice as long. Table 6 presents the data obtained on the life span of wild-collected hibernating females (except *occidentalis*, which were laboratory-reared) exposed to normal winter temperatures at low elevations in north-central California. Sugar and water were available to the caged specimens, as in nature the adults are free to move about on warm days and obtain these items necessary for survival. The age composition of the specimens obtained in the field could not be determined. *A. franciscanus* appeared to be the least tolerant of the prolonged (fluctuating) winter temperatures of the Sacramento Valley. This is compatible with its absence in Idaho, Washington, and Oregon (except the southwestern segment) whereas *punctipennis* and *freeborni* occur widely in these states (Stage, Gjullin, and Yates, 1952).

Tolerance of the adults of these species to high temperature also has been viewed in the laboratory (Bailey and Baerg, 1966). In these tests, specimens were not preconditioned (acclimated) before exposure. The purpose of the experiments was to demonstrate that innate differences in susceptibility do exist between species. Under controlled relative humidity conditions, exposure to 110°F for nine minutes produced 100 percent mortality of all laboratory-reared specimens except *franciscanus*. Female *franciscanus* survived up to 14 minutes, while males succumbed in one-half this time. High temperatures (90°F and above) in the field have a depressing effect on the adult population of *freeborni* (Bailey and Gieke, 1968). Also, *punctipennis* becomes scarce in hot summer weather; King, Bradley, Smith and McDuffie (1960) reported similar observations in Louisiana. The coastal species, *occidentalis*, is prevented from invading the valleys opening to the coast by summer isotherms. In cool summers, penetration into the interior is greater but still very limited. Optimum conditions for this species are found at Pt. Reyes Station, having very cool summers. The maximum reading at which *occidentalis* has been collected in a resting site is 88°F. In the hot desert region, *franciscanus* is the only anopheline able to survive. We have collected adults in a culvert at Mecca at greater than 95°F. This species was commonly found in resting sites at the periphery of the Sacramento Valley at 95-97°F. On one occasion only *punctipennis* was collected at 94° and *freeborni* at 101°. These isolated cases are significant primarily in that they indicate the approximate tolerated maxima of individuals before they may attempt to relocate themselves under natural conditions.

In field breeding sites larvae of the four species have been taken at water temperatures in the 91-99°F range. *A. punctipennis* larvae have been found at a low of 44° and the others at approximately 55°. Laboratory experiments demonstrated that at 43°F all *franciscanus* first instar larvae die within four days, whereas *freeborni* and *punctipennis* survive twice as long. This would suggest that in a cold spell in early spring after egg-laying has begun, *franciscanus* could be eliminated more quickly. Nonacclimated laboratory-reared larvae also were tested for tolerance at 108°F. Data gathered indicated *franciscanus* has the greatest and *occidentalis* the least tolerance to this high temperature. In each species, a decreased tolerance was exhibited by the succeeding instars. Similar findings with *freeborni* and other anophelines have been published by Barr (1953).

Strains of *franciscanus* from the far ranges of its latitudinal distribution apparently have a correspondingly greater ability to withstand the respective temperature extremes. This capacity is evidenced by the high density of larvae of this mosquito in algal mats in receding pools in hot creek beds in summer. Seasonal differences in larval tolerance were illustrated in *occidentalis* by a laboratory experiment. Early season first instar larvae suffered 99 percent mortality when exposed five minutes in water with a temperature of 108°F. In sharp contrast, late season larvae exhibited only 17 percent mortality. Fourth instar larvae of *occidentalis* reared at 60° and 80° exhibited a marked increase in ability to withstand the temperature range at which they were reared. Similar tests were not conducted with other species. We have found in other tests, utilizing a thermal gradient tank with water ranging from 38° to 105°F, that larvae of *freeborni* and *punctipennis*, and *occidentalis*, when introduced at the 70-75° area distributed themselves randomly. Individuals moving into the lower range were killed or became moribund as did those reaching the 93-105° area.

Experiments on the effect of water temperature on the growth of *freeborni* larvae (Bailey and Gieke 1968) showed that this mosquito could tolerate fluctuating (natural) winter exposure in the 40-72° range (mean 52.6°), but only a few individuals matured, and after 81-84 days. In the laboratory, at a controlled temperature of 55°, which is near the threshold for completion of development of each stage for all four species, larval growth of *freeborni* was completed in 31-62 days with a 66 percent mortality. The maximum temperature at which *freeborni* immatures can develop successfully is between 90° and 95°, with a mortality of about 90%. These latter studies were made to provide a general tool for determining population development in rice fields. Variations in the mortality of early and late blood larvae to high temperature and other details remain to be investigated.

It is obvious that the late instar larvae can move about quickly and, in a few inches, can find lower surface water temperatures (in shade among plant growth, or debris) in the summer thus avoiding lethal extremes. This perhaps compensates for their decreased tolerances in comparison with the early instars. However, in the late winter an entire population is chilled and individuals are not able to seek a more favorable environment.

In concluding this phase of the subject, namely, the limitations of anophelines to or by temperature, one has to "read in" the factors of inherent resistance and adaptability. Additionally, it must be emphasized that laboratory experiments expose the organism to artificial conditions not found in nature.

Many other factors, both physical and biological, have their influence on mosquito larvae. Some of these are readily measurable and others are quite elusive and difficult to record in the aquatic environment. Since anophelines are surface feeders, water depth apparently is of little direct importance. Larvae can be collected at the margins of reservoirs, lakes, and deep forest pools, regardless of the total water depth. Water movement, however, is quite critical. Undisturbed water is necessary for feeding, pupation and emergence of the adult. The wind-swept shoreline of a pond or lake will have few larvae in contrast to the lee side. Occasionally, larvae in small numbers can be found at the edge of a canal or stream bank among algal growth or patches of grass, but away from this limited protection they are swept away by the water flowing past. Algal mats anchored in a slowly moving stream can support larvae on the surface even if the water flows beneath the algae.

In the distributional study of *freeborni* larvae in rice fields Markos (1950) stated that "variations in the density of the rice plants within normal field limits had no apparent influence on the number of larvae that developed". Research personnel at the Tennessee Valley Authority water impoundment also studied *A. quadrimaculatus* larval density in detail in relation to the type and density of vegetation. Erect, emergent vegetation supported, or rather offered protection, to the heaviest concentrations of larvae. Our observations on *freeborni* and *punctipennis* in particular indicate this condition: reeds, erect grasses, *Typha* sp. and similar plants, (as well as watercress in the case of *punctipennis)* harbor the largest populations. Floating vegetation, particularly a heavy growth of *Lemma*, can exclude mosquito larvae.

As anopheline larvae increase in size they have a tendency to scatter and distribute themselves. When a larva comes in contact with other larvae, it readily moves away from them. Crowding of the larvae rarely was observed in the field. There appears to be some competition, however, for the most favorable environmental conditions in relation to protection, shade, food, and temperature. Our records seldom show more than 10-15 fourth instar larvae taken at one time in the standard type of dipper. Much larger numbers of early instar larvae, especially *franciscanus* (in algal mats), often are collected.

In the laboratory, crowding is a factor that must be considered in maintaining strong colonies and a dependable supply of larvae. In the standard white enameled pans normally employed for larval rearing, about 12 x 7 inches, the concentrations of larvae had to be serially reduced during growth. *A. freeborni* and *punctipennis* are most adversely affected by crowding; 100 fourth instar larvae per pan was about the maximum number that could be reared without nearly constant attention. The tendency of the larvae to cluster in the corners resulted in injury by the chewing of their bristles. The large larvae could not maintain themselves at the surface film without a complement of supporting bristles, and sank to the bottom where they died after a few hours. These larvae also were rendered more susceptible to secondary bacterial infection (particularly *Pseudomonas*). Feeding every few hours reduced "cannabalism" and aided in separating the larvae for longer intervals. Grass clippings, algae, or excelsior in some cases, were used to provide additional feeding surfaces. Up to 300 larvae per pan of *franciscanus* could be reared successfully. While the additional factors of temperature and light were involved, our laboratory investigations have shown the more rapid growth rate and agressive character of *franciscanus* enable this species to clearly assert its dominance when reared in pans with the other California anophelines.

Our collections in northern California have been made in waters varying in pH from 6.4 to 10.3. Not all four California anophelines have been collected in water within this range of hydrogen ion concentration, although preliminary laboratory experiments indicated they can tolerate these extremes. Essentially, the pH of fresh water suitable for anophelines in this area is not of sufficient acidity or alkalinity to prohibit larval development.

Of the three anophelines inhabiting the coastal area, *occidentalis* was collected in the most highly brackish water, i.e., up to 55.7% sea water. Two other species, *punctipennis* and *franciscanus* were found in concentrations of to 20%. The highest salinity in which we have collected *occidentalis* has been 1.95% dissolved salts, indicating it readily tolerates brackish conditions found at the mouths of our small coastal streams.

Culicidologists have made frequent mention of anopheline preference for "clear, fresh, sunlit water". Among the California species, all but *punctipennis* are found in the greatests abundance in a sunny location. We have commented previously upon this phase of larval preferences and its possible over-emphasis (Bailey and Baerg, 1966). All four species have been reared in both complete darkness (with the exception of a few minutes each day to service the pans) and continuous light. It should be noted that under these artificial conditions no predators or toxic by-products from a biological complex were allowed to exist or accumulate. This leads to a brief mention of such influences.

In our studies we have not explored nutritional and antibiotic factors, or predators influencing larval populations. Christensen (1968) examined *occidentalis* larvae for protozoan parasites and believed them to be of greater importance than generally realized. Considerable effort to determine the antibiotic factors of blue-green algae in rice fields which appear to inhibit anopheline larval development has been made with little success by Gerhardt (1956) and Washino (1964). Markos (1950) earlier had reviewed this and related topics. In the past few years *Gambusia* "seeding" of rice fields in large quantities appears to offer the best promise of successful manipulation of the larval predators.

CONCLUSIONS.—If the "growth" of the state continues, together with the exploitation of the natural environment, we foresee a continual reduction in the acceptable breeding sites of *occidentalis* along the narrow coastal strip and, on the other hand, an increase in the local populations of *punctipennis* in the foothill areas. Recreational and second home developments in the Sierra and coastal mountain areas from 1,000 to 3,000 feet elevation have impounded water and, depending on particular plant growth and water management, additionally may favor *freeborni*. With present irrigation practices, the aggressive, very adaptable *freeborni* is given almost unlimited opportunity to multiply in rice fields, ponding from irrigation of many crops, and in weed-choked, shallow canals. Control of this principal pest species (and potential malaria vector) will need to be continued indefinitely. The fourth species, *franciscanus*, undoubtedly will persist innocuously in desert and outlying hill areas, in sunlit shallow puddles and stream pockets, remaining through late summer and fall if waters are not too heavily polluted. It is well known that modern urbanization and malaria do not go forward together. Thus, over a progressively smaller area in the state we should continue to observe the condition known as "anophelism without malaria".

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A MOVEMENT OF *AEDES NIGROMACULIS* IN SALT LAKE COUNTY, UTAH

Jay E. Graham[1] and Glen C. Collett[2]

Movements of *Aedes dorsalis* over long distances in Salt Lake County, Utah, have been observed and documented. Similar movements of *Aedes nigromaculis* are suspected but the species is not abundant and opportunities for close observation of movements have been lacking.

In late June of 1971, a large mixed brood of *A. dorsalis* and *A. nigromaculis* emerged on the 1600 acre Hogle farm about eight miles west and north of Salt Lake City. About two-thirds of the mosquitoes were *A. nigromaculis*. Intensive inspection disclosed no other important source of this species at this time and the sources found were controlled.

On July 8, a New Jersey type light trap eight miles south and slightly east of the Hogle farm captured seven *A. nigromaculis*. This trap had only taken six *A. nigromaculis* in the ten previous years and there is no known source of the species within four miles of the trap. On July 12, the number taken was 11, on the 15th, six were taken and one on the 19th. Residents in the vicinity of the trap were the closest human population to the Hogle farm and numerous complaints were received, particularly on July 12 and 13. After this, complaints rapidly decreased. All investigations of complaints showed both *A. dorsalis* and *A. nigromaculis* present with the latter being more abundant.

Human population is sparse south of the trap and about a mile from the trap, the land is dry foothills without agriculture or human population. Some eight miles south and east of the trap and 16 miles from the Hogle farm, a golf course, Westland Hills, has been developed. On July 12, this golf course reported large numbers of mosquitoes. Investigation proved them to be *A. dorsalis* and *A. nigromaculis* with the latter being more abundant. No known mosquito source exists within five miles of the trap and the closest are to the east. No *A. nigromaculis* sources or adults were found to the east until after this movement and residents in these areas reported no mosquito nuisance.

On July 19, some *A. nigromaculis* were taken in traps still further from the source and these may have been migrants, but the evidence is inconclusive.

[1]South Salt Lake County Mosquito Abatement District, P. O. Box 367, Midvale, Utah 84047.

[2]Salt Lake City Mosquito Abatement District, 463 North Redwood Road, Salt Lake City, Utah 84116.

MAPPING MOSQUITO PRODUCTION AREAS IN IRRIGATED PASTURES AS AN AID TO SOURCE REDUCTION

David E. Reed and Gerald W. Fipps

Fresno Westside Mosquito Abatement District

P. O. Box 125, Firebaugh, California 93622

INTRODUCTION.—Increasing resistance of pasture mosquitoes to available insecticides had made reduction and/or elimination of mosquito sources imperative in several California mosquito districts. The approaches to this common problem have been as different as there are districts. It is logical, however, that a thorough knowledge of the extent of the mosquito producing area in a pasture is a prerequisite to arriving at an ultimate solution to the urgent problem.

A rating system of evaluating mosquito producing potential has been reported by Davis (1961) and was tried by one mosquito control district in California (unpublished). This rating system lists and grades the key factors influencing mosquito production in agricultural lands and may become a most important tool for future mosquito source prevention programs. The rating system may be used effectively to determine the best corrective measure to be taken to eliminate a source.

The most common practice in California mosquito control has been to use mosquito control activity (spraying) and the cost thereof as the primary method of evaluating need for source reduction (Husbands 1970). Engineering surveys of irrigated pastures have been used in mosquito control. This service has been primarily used to determine general slope of land so that proper drainage facilities could be constructed. Some districts have considered actual mosquito production areas in pastures but mainly in general terms. Little, if any, precise biological data are available.

Mapping of water areas on 280 acres of irrigated pastures at the time of *Aedes nigromaculis* fourth instar larvae and pupae was done in Tulare County (Reed, unpublished) during three periods of the mosquito season (April, June and August) in an attempt to delineate extent of mosquito production areas in pastures and also, in effect, survey the low spots of the land. Seasonal changes of ponding areas in pastures have also been reported (Husbands, 1953).

There are approximately 10,000 acres of irrigated pastures in the FWMAD. The bulk of this acreage is found between the communities of Mendota and Kerman. A block of about 3,800 acres in this area belonging to two owners was selected for study in 1971. The purposes of this study was to determine the adult mosquito production area in irrigated pastures; to develop and/or improve field techniques for evaluating these mosquito sources; and to evaluate the work effort required to obtain these physical and biological data. The goal is the eventual incorporation into the Districts's control program of a systematic evaluation of all mosquito sources for their ultimate reduction and/or elimination.

DESCRIPTION OF STUDY AREA.–Due to the large area involved in this study, a pasture by pasture description would be too extensive. The most practical method is to describe each ranch and its operation.

The two ranches are located within a 15 square mile area bounded roughly by the Mendota Pool to the west, Fresno Slough on the south, Placer Avenue to the east and Highway 180 on the north. The area in pasture is almost equal in both ranches.

Description of Ranch "A".–Ranch "A" is owned and operated by a large corporation with headquarters outside of California and is located in the northwesterly portion of the study area. Twenty-six irrigated pastures with a total of 1,862 acres were used. Pasture size ranged from 10 to over 200 acres for an average of 71.77 acres. All pastures were ¼ mile in length. Border check widths ranged from 30 to 100 feet. Field age ranged from under one to over ten years. In most cases, pastures were developed from native, undisturbed land.

Soils.–Soils were mainly of the Waukena, Pond and Traver series with moderate to high salt content (some "black alkali" is contained in the Waukena soils). These are, generally, poorly drained shallow soils with a natural slope of 0-0.1 feet.

Irrigation.–Water for irrigation was pumped from ten wells into pipelines or open ditches. About 416 acres of pasture were irrigated via underground pipe and valves. Water from these wells was also used to irrigate other crops on the ranch (alfalfa, sugar beets, milo). Irrigation started in early March and continued, on about a ten-day cycle, through October. Border checks were flooded for about 24 hours. In many cases water had reached the low end of the check before irrigation was stopped. There were from four to seven irrigation settings per field with 3 to 12 border checks flooded at one time in a pasture. The length of time to complete the irrigation of a field was directly related to the number of border checks irrigated each day and/or the size of the pasture.

Drainage.–All fields were supplied with a "V" ditch drain at the low end. This "V" ditch produced a mound or ridge on both sides of the ditch. A cut was made through this ridge on about every fifth "key" border. A drain cut between border checks was made at the low end of the two adjacent border checks to allow water to flow laterally into the "key" border check. Several fields had cuts into the drain ditch in only one out of 20 borders. Field drains emptied into a common drain which led to a: (1) sump which pumped water into an irrigation ditch and was reused, or (2) gravity flowed into slough and water reused, or (3) gravity flowed into native pasture where it spread out.

Pasture Maintenance and Management.–Pasture border levees were mainly constructed and repaired or removed with a border disc. The effect was to make a small ditch along both sides of the border for the length of the field. When borders were "reconstructed" large clods of soil made up these borders and no attempt to break up the clods was made.

There was generally no cattle rotation on fields over 80 acres in size. Some cattle rotation was practiced in a series of seven fields about 40 acres in size. However, no routine pattern was detected and very little attempt was made to move livestock from fields being irrigated. During the winter months cattle were removed to mountain ranges.

A practice of mowing tall grasses and plants was not followed, and, in some fields, it appeared that insufficient livestock were placed in fields to keep them fed down.

Pastures were seeded with a combination of grasses and legumes. Most fields had a poor to excellent cover of tall fescue,some rye grass, and little of any other pasture grasses or clovers. Weeds covered large portions of many pastures. The most common weeds were foxtail, rabbitfoot-grass and yellow star thistle. Portions of many fields were almost without plant cover. Bullrush and cattails were found where water persisted from one irrigation to another.

Description of Ranch "B".–Ranch "B" is owned by a company headquartered in California. The ranch is located in the southeast portion of the study area. It consisted of 54 irrigated pastures ranging in size from 16 to 54 acres and comprised a total pasture area of 1,945 acres. The average size of each pasture was 34.73 acres.

Pasture lengths ranged from under 1/8 mile (triangular-shaped fields) to ½ mile in length. Except for three fields, border strips were 40 feet wide. Border levees were high, wide, and gently sloping.

Pastures' age ranged from 2 to over 13 years of age. The bulk of the acreage had no agricultural crop prior to development into pasture. About 200 acres of old pastures were redone in 1963 and 1964 and about 160 acres had been in alfalfa prior to pasture.

Soils.–Soils are mainly of the Fresno and Traver series with intrusions of Pond and Cajon. Many desert playas are found throughout the area. These are all rather shallow soils with moderate to heavy salts and slopes not over 0.1 feet to 100 feet.

Irrigation.–All pastures were irrigated from pipelines. Each border check had a valve leading from the underground pipeline. There were 15 wells supplying water for seven irrigation pipeline systems. Each border check was flooded for about 24 hours, the water removed from check when it had reached 200 feet, more or less, from the end of the field. Irrigation settings ranged in number from two to six per field depending upon width of the field, and there were 1 to 15 borders flooded at one setting in a given field. Irrigation cycle was 10 to 15 days.

Drainage.–A "V" ditch, with banks at both sides, constructed to grade, was used as a drain at the low end of a fields. Cuts into the drain were made in every third or fifth border strip much as described in Ranch "A". Six sump pumps pumped drainage water back into the irrigation pipeline. There were, however, six drain systems which spread into undeveloped lands.

Pasture Maintenance and Management.–Each year, during late winter, border levees were repaired by filling breaks or low spots with soil brought in from other areas of the ranch. All fields were fertilized prior to the first flooding in March.

With few exceptions there were no cattle on wet fields. Cattle were removed to the mountain ranges during the winter.

Pasture mixtures of grasses and legumes were planted. Bermuda grass was common in many fields. In most fields these plants are in evidence in good proportion. Weeds are in evidence but restricted to some of the more difficult areas to manage. When and where necessary tall grasses were mowed, windrowed and baled. Most common pasture plants observed were: tall fescue, birdsfoot clover, ladino clover, bermuda grass and annual rye. Most common weeds observed were: foxtail, bullrush, salt grass.

MATERIALS AND METHODS.—In previous studies (Husbands 1953) it has been found that ponded areas in irrigated pastures become larger as the season progresses. The aim of this study was to evaluate as many pastures as possible during the period when mosquito producing ponds were at about the maximum in size. It was reasoned that any ponded area found during this period is a potential problem now or will be in future years should farm management practices remain unchanged. For the purpose of this study, therefore, data collected only during July and August were used.

An experienced District Inspector-Operator (co-author) was assigned the full-time task of collecting field data. Data were collected from each irrigated pasture during one irrigation only. The study area was surveyed for daily irrigation patterns. Once irrigation was started on a pasture, it was scheduled for mapping. Coordination with the zone operator in the area was necessary to prevent chemical treatment of the field prior to sampling and mapping. Dates of each irrigation setting were recorded for each field. About 48 hours following each irrigation setting, the flooded area of the pasture was inspected for mosquito development. An estimated date was scheduled, then, for larvae sampling and mapping of water areas.

Mapping of water areas was done when mosquito larvae reached fourth instar or pupae. Occasionally late third and early fourth instar larvae production areas were recorded for each field on work maps which consisted of 8½ x 11 inch quadrille paper. Map scale varied somewhat depending upon size of field to be mapped. Water areas were drawn on maps in their approximate location and size by pacing the length of the checks. Field map records were transferred to maps scaled at 165 feet to 1 inch. Areas known to be dry on previous inspections were not paced. Mapping continued in the field during that day up to the point where third instar larvae were first observed.

Mosquito larvae sampling usually preceded mapping. For sampling purposes pastures were divided generally into three parts: the upper 1/3, middle 1/3 and lower 1/3. Drain ditches at the low end were considered as part of the lower 1/3. Waters leaving the pasture were also sampled and mapped but considered separately. A ten-dip transect across the checks of the area mapped that day was taken in each of the three pasture divisions. In divisions which had no ponding, sampling was considered as zero dips. A pasture, then, which was mapped, in part, on two occasions during one irrigation and which had ponding throughout the field would be dipped 60 times. If, in this same pasture, ponding was only in the lower 1/3, only 20 dips were taken.

Samples were taken with a one pint white enamel dipper having inside diameter of 4.5 inches. Each sample of ten dips was concentrated with a hand concentrator as described by Husbands (1969). Mosquito larvae were killed and preserved in 50% isopropyl alcohol and later identified to species and instar, in the laboratory.

Observations on pasture, water, and livestock management were noted.

Field temperatures were taken but mean general area temperatures were computed from the daily records of the Firebaugh Canal Company.

Mosquito production area was measured by a grid system made to correspond with the map scale. Each grid square was equivalent to .025 acres. In general a grid was counted when a pond was entirely within one grid (regardless of its size) or when ponding extended about half way or more into grid from another grid. Grids with two or more ponds were considered as one.

Mosquito production index has been calculated by Harmstron, et al. (1956) as the average number of fourth instar and pupae per dip times the breeding area in acres. Only those water areas containing larvae are included in these calculations. Surface area per ten dip sample was calculated by Hagstrum (1971) as 1.6 feet^2 which can be equated as 6.25 dips per square foot.

For the purpose of this study all potential mosquito producing ponds in an irrigated pasture were used to calculate field production index. By covering a distance of about a foot at a depth of about one inch below the water surface, between three and four dips are required to dip one square foot of water surface. In calculating the mosquito production of each field the conservative three dips per foot^2 was chosen. To arrive at the calculated field production the formula used was then:

$$\frac{3d \times 43{,}560\, Pa}{fa} = fp$$

where:
- d = larvae per dip
- pa = mosquito production area
- fa = total field acres
- fp = field production index

RESULTS.—There were 68 of the 80 irrigated pastures in the study area which were sampled and mapped during the two month period starting June 18 and ending August 12, 1971. The area of pastures mapped amounted to over 80% of the study area (3,071.7 acres). There were 24 fields (35%) which dried up completely, thus producing no mosquitoes.

Pastures in the study area were divided into five year age groups, and are summarized in Tables 1 and 2. The first five-year grouping was divided into two parts. The bulk of the pastures were found in the 6 to 10 years group (Figures

Table 1.—Summary of number of pastures in each age group and survey accomplished during 1971 in study area.

Number of Pastures	1-2	3-5	6-10	11-15	Over 15	Total
Total	6	7	52	8	7	80
Mapped	5	5	46	6	6	68
Dry	5	3	14	0	3	25
With Ponds	0	2	30	6	3	41
Mosquito Producing	0	0	2	0	0	2

Table 2.–Total acres of pastures in each age group showing water condition at time of survey.

Acres of Pastures	1-2	3-5	6-10	11-15	Over 15	Total
Total	446	385	2,449	263	265	3,808
Mapped	214	233	2,199		245	3,071
Dry	171	120	524		121	936
With Ponds	43	113	1,675	180	124	2,135
Mosquito Producing	0	113	314	0	124	2,049
Total Ponding Area	1	19		180	4	341
				180		
				3		

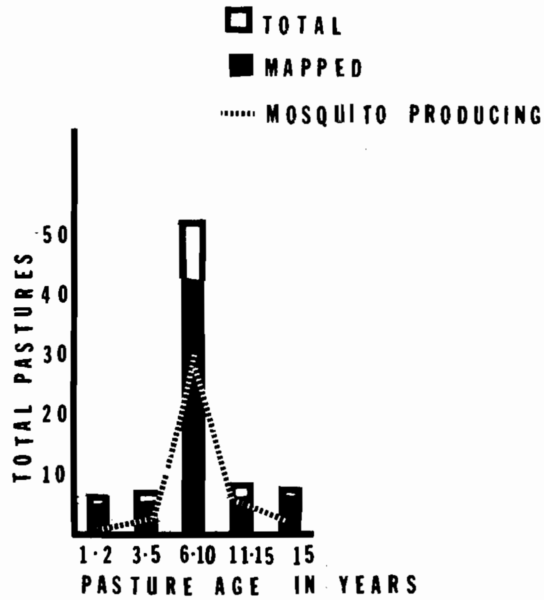


FIG. 1

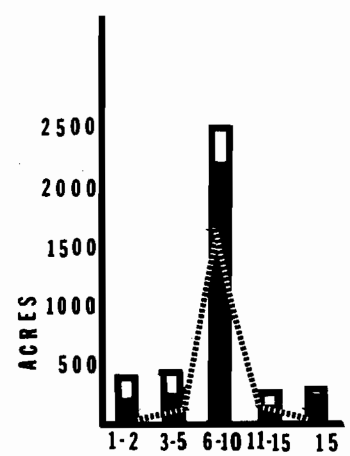


FIG. 2

1 and 2). The majority of the pastures producing mosquitoes were also found in this age group.

It has been commonly presumed that older pastures are more likely to become mosquito problems. Our results generally support this idea (Figures 3 and 4). All pastures in the 11 to 15 year age group were mosquito producers. However, the average size of the source (ponded area) was the smallest in this same age group (Figure 5). There were no pastures 1 to 2 years of age which produced mosquitoes (Figure 3).

Calculated mosquito production was greatest in pastures over six years old (Figure 6). However, this may not be a true indicator of production potential in that the greatest acreage of pastures is found in this age group (Figure 2). When considering total pasture acreage, over 60,000 mosquitoes per acre were produced in pastures of this age group. When considering the ponded area only of each age group, the 11 year group had the highest production per acre--over 600,000. This means that the sources were smaller in the 11 year group, and that the larval densities were much higher than in the 6 age group.

Aedes nigromaculis and *Aedes melanimon* were found alone and together in pastures. However, during the period of this study all pastures producing mosquitoes had *A. nigromaculis* but only 57% contained *A. melanimon*. *A. nigromaculis* densities increased as fields aged, whereas densities of *A. melanimon* dropped (Figure 8). Most of the pastures were developed from native land high in salt. Could the success in "desalting" this land be measured by the drop in numbers of the more salt tolerant *A. melanimon* and the subsequent increase of the less salt tolerant *A. nigromaculis?*

Mosquito producing pastures were divided into three groups: 1) those with producing areas at the lower 1/3 of the field only, 2) those with producing areas in the lower 2/3 of the field and 3) those with mosquito production area scattered throughout the field. All pastures in this study fell into the first and third of these groupings. There were eight pastures with production areas scattered throughout the pasture and were all located in Ranch "A". In these fields, ponding tended to increase down field (Figure 9). Densities of *A. nigromaculis* also increased in a down field direction (Figure 10). The differences, however, are not very great. There were greater differences in larval densities between the lower 1/3 of pastures in Ranch "A" with ponded area throughout the field (L_T) and pastures with ponding at the lower 1/3 only (Lo.) (Figure 11). Larval densities in Ranch "B", which only had ponding at the lower 1/3 of the field, were also higher than those fields in Ranch "A" with ponding throughout, but lower in density than similarly described fields in Ranch "A". The existence of a drain may aid substantially in the concentrating of these larvae at the low end.

DISCUSSION.–The survey of irrigated pastures used in this study was biological-engineering in nature in which existing water was used as a level at the time of mosquito production. Although no measure was made of the grade of the land, good indications of the grade can be made simply by observing the water patterns in the field. Generally, pastures with large ponded areas scattered throughout the field have been leveled with almost no grade. Fields so leveled require water management completely different from those fields which have a grade of 0.1 ft. per 100 ft. or more. For example, the construction of borders in flat fields must be higher and wider to better handle a greater head of water.

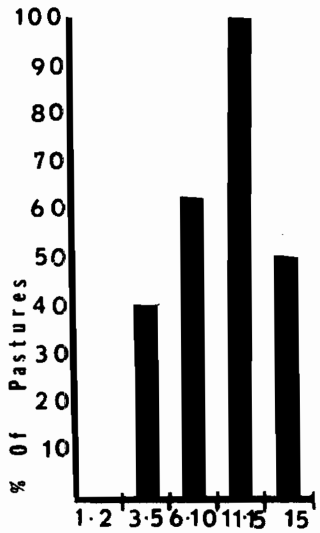


FIG. 3

FIG. 4

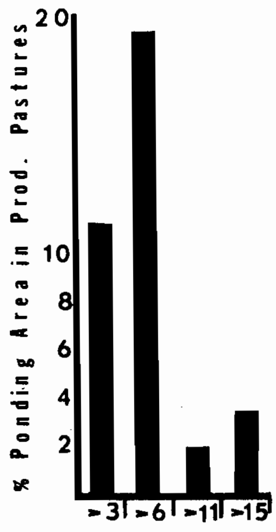
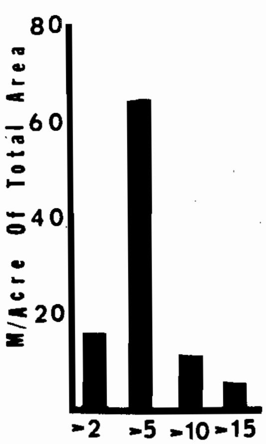


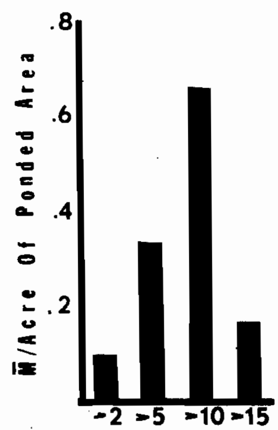
FIG. 5

PASTURES PRODUCING MOSQUITOES

Figures 12 and 13 illustrate pastures with ½ mile and ¼ mile runs in which ponding is at the lower end. Although a drain exists in both fields it is obvious that something is impeding complete drainage. The "V" construction of the drain ditch provides this impediment. By eliminating the up-field bank of this drain, reduction of the ponding would be almost complete. Water management may care for the balance of the ponding.

The conditions illustrated in field 23 (Figure 14) represent a completely different problem. The major ponding areas in this pasture are found in the upper 1/3 indicating almost no grade. Soil compaction and sinking has occurred in this upper portion. It can also be noted that once irrigation waters passed mid-field, drainage was possible. Compacting and ponding due to cattle trails are easily observed in the almost diagonal line of ponds starting at almost midpoint in the pasture and proceeding in a southeasterly direction. Longitudinal ponds found on margins of checks adjacent to border ridge are borrow pits or channels the result of building the pasture borders with a border disc. Nothing short of completely redoing this pasture will eliminate it as a source. However, by rebuilding the borders leaving no





PASTURE AGE — IN YEARS

FIG. 6

FIG. 7

Aedes nigromaculis PRODUCTION PER ACRE OF IRRIGATED PASTURE

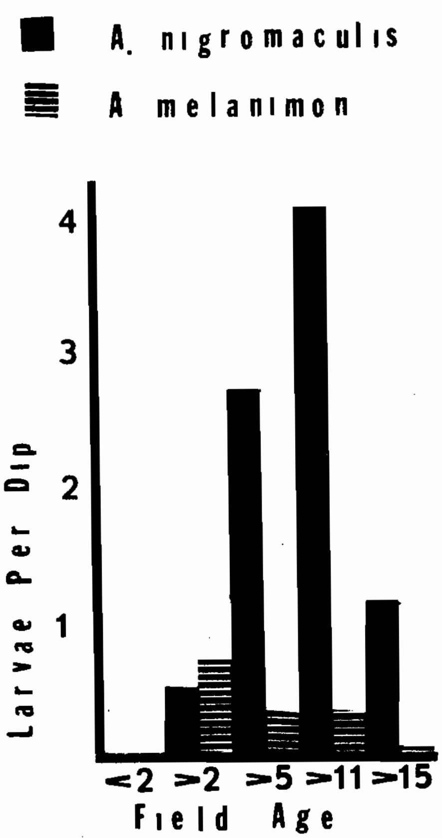


Fig. 8

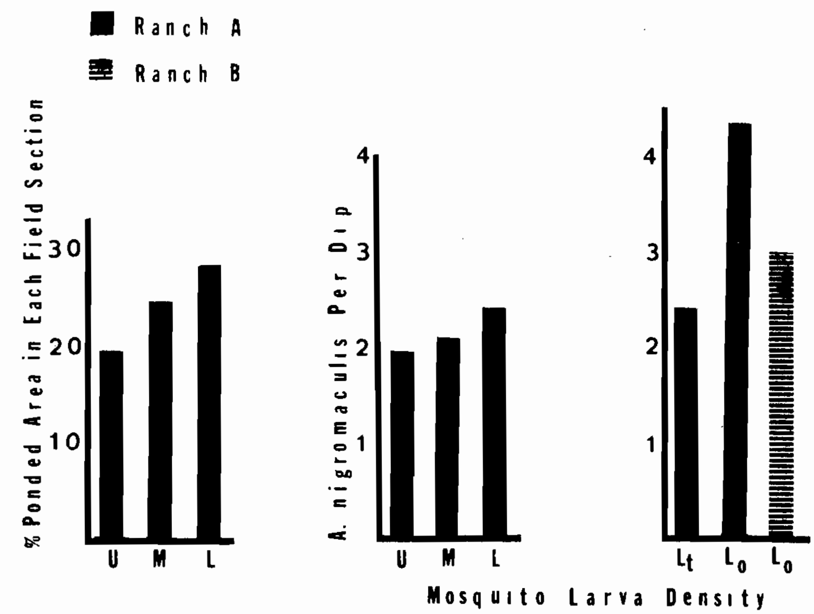
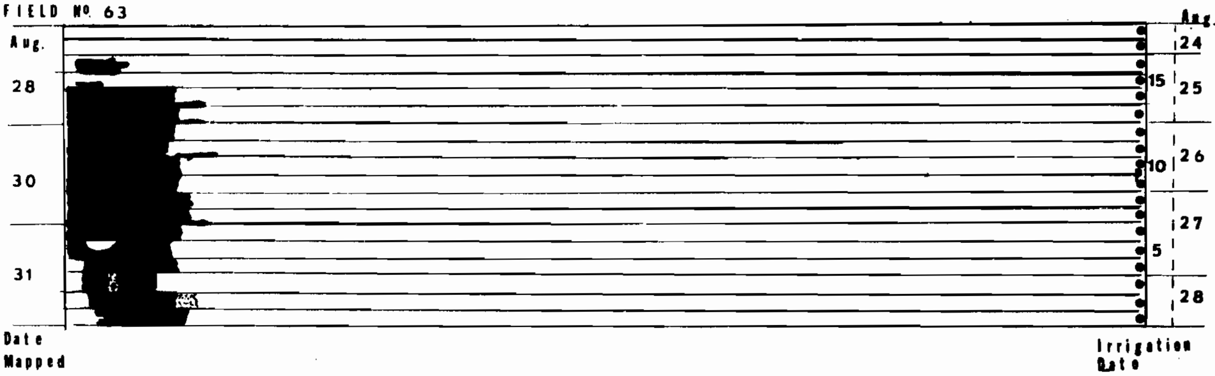


Fig. 9 Fig. 10 Fig.11

COMPARISON OF PONDS BY LOCATION IN THE IRRIGATED PASTURE

FIG. 12
FIELD No. 63



borrow pits, eliminating the up-field levee of the "V" ditch drain, the application of soil conditioners, and rapid flooding of each border strip, the mosquito source may be materially reduced.

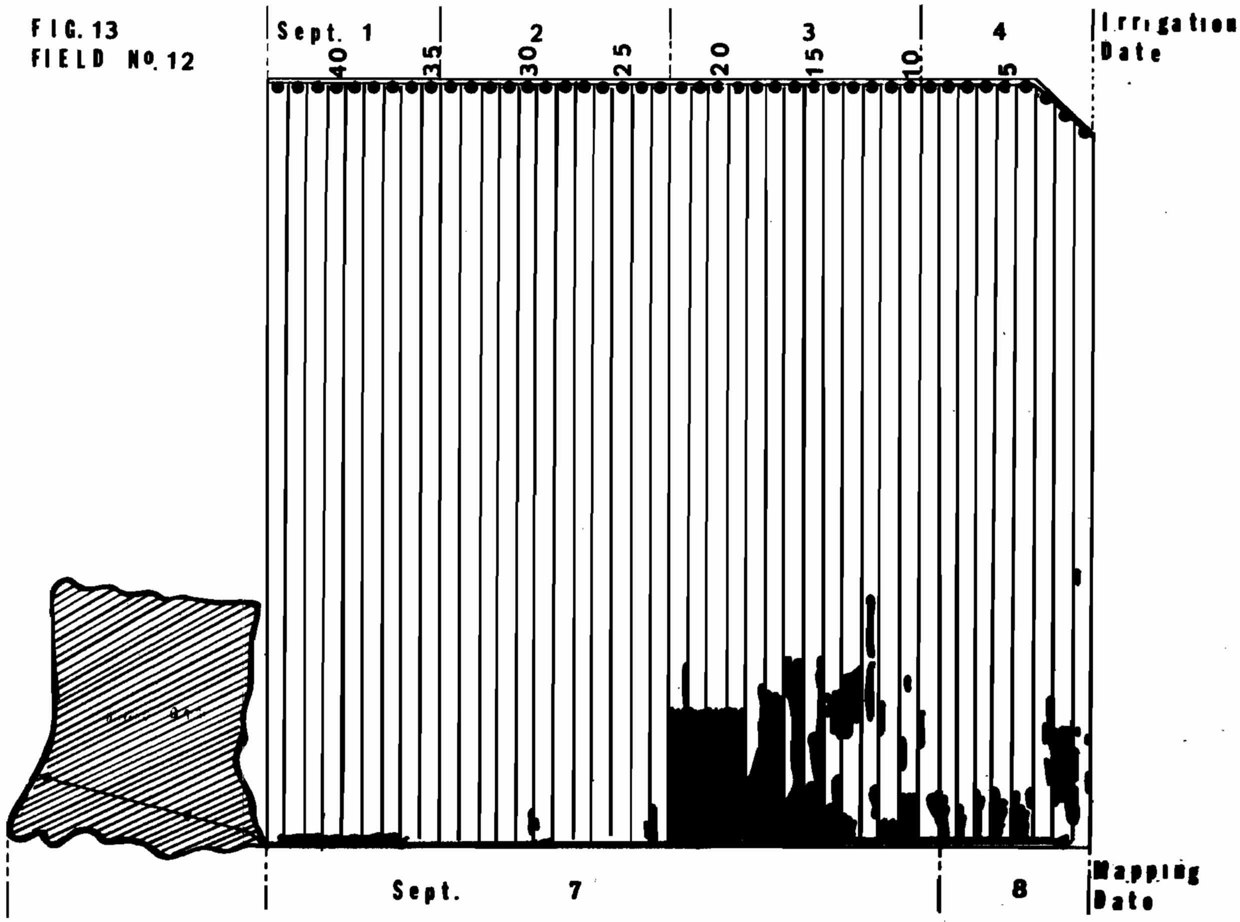
The methods used to acquire the information contained in this study obviously took time. The field data were collected in its entirety by the co-author. During the period of the study there were 396 working hours involved. About 40.9% of this time was spent collecting field data and 28.4% of the time was spent in the lab and office. A large block of time (30%) was spent in other related or unrelated District activities (Figure 15).

The objective of this study was to map production areas of 80 irrigated pastures which cover roughly 3,807 acres of land in two months during mid-season (July and August). This was 80% accomplished. However, had all the time for activities unrelated to the project gone to that project, over 3,782 acres would have been mapped. It may be then concluded that a mosquito abatement district can systematically make precise maps of producing areas in irrigated pastures at the rate of almost 2,000 acres per month per operator using skilled or semi-skilled personnel.

By incorporating a routine of precise mapping of mosquito producing areas in irrigated pastures and other similar sources into the district's program, several benefits and aids can be expected towards the elimination and/or reduction of these sources. It can:

1. Help in the planning of the district's source reduction program by indicating where the district needs to put its effort.
2. Serve as an aid to source reduction planning by generally categorizing pastures, i.e.: a) those requiring improved water management only, b) those requiring a drain or return system, c) field renovation, d) field releveling.
3. Be used to estimate the rate in which the source reduction problems can be tackled. This has certain definite budgetary implications.
4. Be used as a tool in talking to the landowner.
5. Be used to periodically re-appraise the problem.
6. Aid in future information-gathering of data from the total pasture environment.

FIG. 13
FIELD No. 12



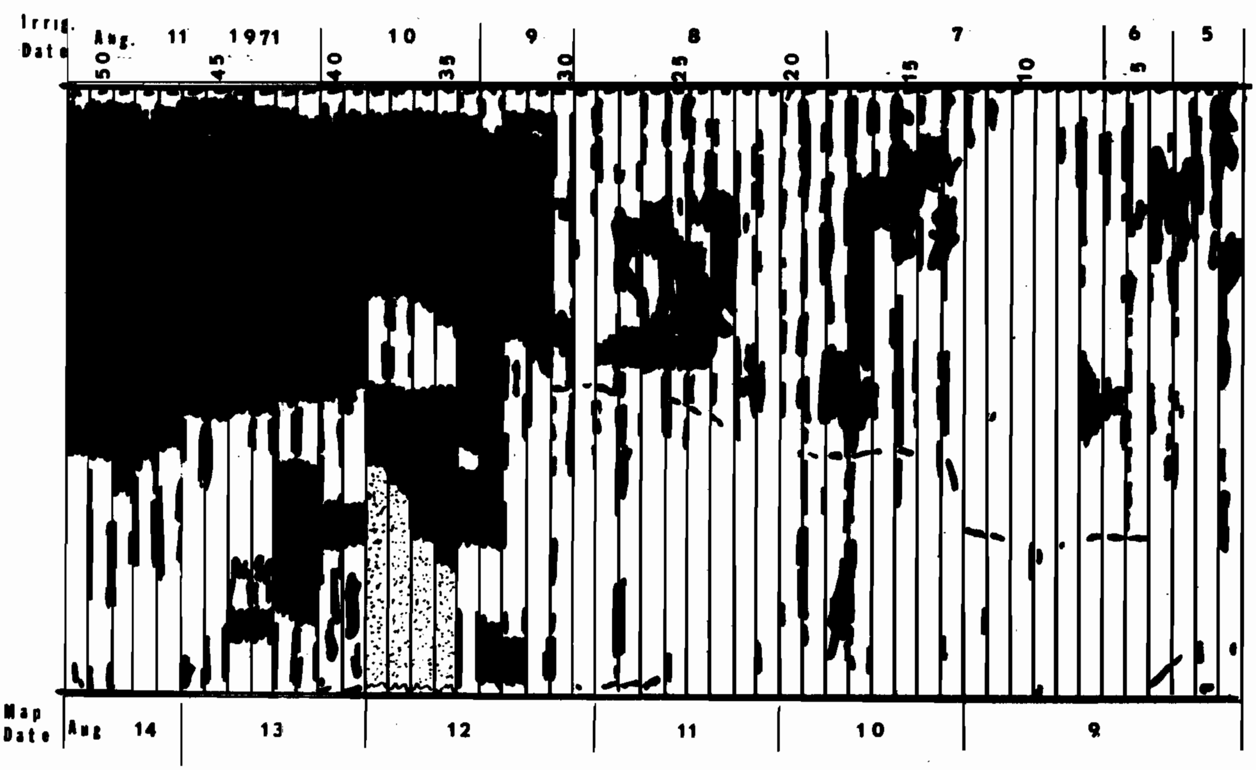


FIG. 14
FIELD No. 23

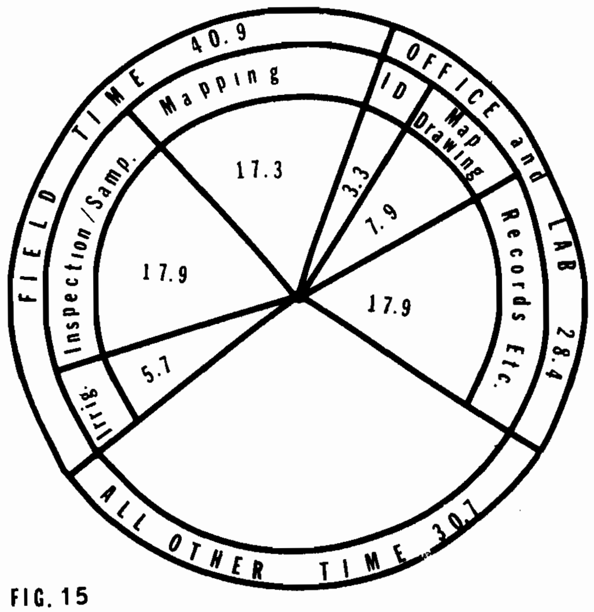


FIG. 15

OPERATOR TIME DISTRIBUTION DURING JULY AND AUGUST, 1971, EXPRESSED IN PERCENT OF 396 TOTAL WORKING HOURS

Although gathering of these data as described in this paper is time-consuming and tedious, the time spent may be well worthwhile in the long run. In the future, however, collecting data will be speeded up considerably by the use of aerial photography. But even with aerial photography, ground surveys will form an essential part in the final evaluation.

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PREDATORS INVESTIGATED FOR THE BIOLOGICAL CONTROL OF MOSQUITOES AND MIDGES AT THE UNIVERSITY OF CALIFORNIA, RIVERSIDE[1]

E. F. Legner and R. A. Medved

University of California

Agriculture Experiment Station, Division of Biological Control, 200A Entomology, Riverside California 92502

Predators of mosquitoes and midges that offer the greatest possibility for immediate pest abatement are presently being emphasized at the University of California, Riverside. Some species of fish demonstrated good predatory qualities in earlier research (Anderson and Ingram, 1960; Bay 1968; Bay and Anderson 1965); others imported since August 1971 for their alleged control capabilities now have been observed to possess desirable traits. Several species of domestic invertebrates also are being investigated for use in inundation. This report lists the species presently in culture in outdoor ponds at Riverside (Fig. 1) with data on their origin, biologies, feeding habits and habitat tolerances.

PREDATORY FISH.–Two strains of *Gambusia* from the southeastern United States, *G. affinis-affinis* (Baird and Girard) and *G. affinis holbrooki* (Girard), are being cultured for interspecific competition studies with other fish. The attributes of these species for mosquito control are well known, as well as their inefficiency as predators in habitats with emergent vegetation (Bay 1967; Hoy et al. 1971). *Gambusia* have also been associated with over-production of green algae and subsequent increases in midges. These fish are generally not very useful for control of mosquitoes in temporary water situations and, therefore, are not suitable for *Aedes* or *Culex pipiens quinquefasciatus* control unless planted artificially.

The common carp, *Cyprinus carpio* L., and goldfish, *Carassius auratus* (L.), are effective predators of midge larvae (Bay and Anderson 1965). However, the larger size of the former and habits of muddying water and interference with game fish species by both unfortunately often restrict them for widespread use in insect control (Kimsey and Fisk 1969). We have now secured a variety of *C. carpio*, the Koi, which was purposefully bred in Japan for ornamental ponds. Koi are brightly colored in various hues from gold to light blue and white. They do not become as large as the common variety and are quite tame. Our data show them to be effective in midge and mosquito control in our experimental ponds.

The guppy, *Poecilia reticulata* Peters, originally from northeastern South America, is especially tolerant of pollut-

[1]Research partially supported by grants and assistance from the California Department of Fish and Game and mosquito abatement districts in Southeast Los Angeles, Orange and Riverside counties, and the Coachella Valley.

ed water and is well adapted to sewage oxidation ponds. Although very effective as a mosquito predator, its control capabilities on midges is not yet proven. This species forages more effectively than *Gambusia* amongst aquatic vegetation and algal mats, and its fecundity is greater (Bay 1967). However, being a tropical species, it is less tolerant of cold water than *Gambusia* and declines below 45°F.

The annual fish, *Cynolebias bellottii* Steindachner, with origins in the higher latitudes of South America around central Argentina, is especially adapted to intermittent water if flooding occurs in winter. This fish has sustained itself in shallow (1.5 ft) ponds at Riverside for six years. It is a voracious predator of mosquitoes and midges in cool water and breeds prolifically. The males are iridescent blue during spawning, which takes place scarcely three weeks after hatching. The young fry are capable of consuming great quantities of mosquitoes and midges during this rapid growth period. *Cynolebias* was stocked in the Sacramento Valley rice fields during the mid-1960's; however, it is doubtful that establishment occurred because autumn is the appropriate month for breeding and dried egg incubation areas were not made available. This species might readily adapt to duck club situations where the water is drained during summer months. The eggs of annual fish require at least one month of drought to activate the embryo , which remain viable in,the caked mud of dry pond bottoms (Bay 1966). Little is known about the game qualities of *Cynolegias*, although they rarely reach a catchable size (3-4 inches in length).

The African genus *Tilapia* has recently gained attention in the Southwest as warm water game fish. Three species, *Tilapia mossambica* (Peters), *T. hornorum* Trewavas and *T. zillii* (Gervais), were introduced in California where they are being evaluated for mosquito and midge control. All three consume the floating mats of green and blue green algae, cleaning up their habitat in the process (Fig. 2). In addition, *T. zillii* feeds directly on emergent aquatic vegetation, including cattails under certain conditions of stress. These fish will feed on mosquitoes and midges directly by foraging through the respective breeding sites. At Riverside the growth rate in water at 80°F is rapid, from one to eight inches in two months. They are apparently poorly adapted to sewage affluent ponds as a 1964 study in Santee, California, demonstrated (St. Amant 1966), which could involve high phosphate concentrations as shown in other studies (Hallock and Ziebell 1970).

T. mossambica ranges from fresh to ocean water (Hickling 1961). Cold water of 55°F and below causes its decline and eventual death (St. Amant 1966). Therefore, unless warm water retreats are available, as for a population of *T. mossambica* in the extreme southern part of California, the species declines and must be restocked every year. However, *T. mossambica* is extremely prolific and will normally reproduce to sufficient numbers for mosquito control in 2-3 months after stocking (Hallock and Ziebell 1970).

T. hornorum Trewavas is closely related to *T. mossambica*, with sterile males being produced from the cross between them. These males are voracious predators of benthic organisms and mosquitoes (Hallock and Ziebell 1970) and could be employed where it is not desirable to introduce breeding stock. However, an initial trial with these hybrids in California for midge control was unsuccessful (St. Amant 1966).

There are many species of foreign predatory fish cited in the literature that would make desirable candidates for biological control of aquatic insects. Many of these are listed in Frey (1961) and are of tropical origins. For example, in South America the genus *Geophagus* is reputed for its habits of sifting through the bottom sediments of ponds and lakes extracting benthic organisms for food. In southern Mexico, some species of *Gambusia* exist that possess similar habits. Almost any book on fish contains references to the predatory habits of species that might be worthwhile to investigate. The tropical fish, especially, possess the high fecundity and voracity required for practical biological control.

However, before additional exotic importations are sought, our own native fish fauna will be investigated. Three genera, the chubs *Gila*, the pup fishes, *Cyprinodon*, and the sticklebacks, *Gasterosteus*, have not been studied for their mosquito and midge control potential. These fish have the advantage of being climatically adapted in California and could become desirable insect control predators if introduced into problem areas.

INVERTEBRATE PREDATORS.—For decades the predatory capabilities of hydra (*Coelenterata*) have been lauded in mosquito predation (Hamlyn-Harris 1929; Stephanides,

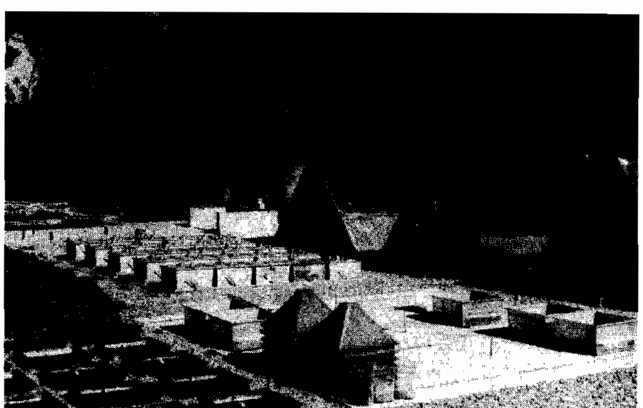

Fig. 1.—Aquatic Research Area of the University of California, Riverside, showing the fish quarantine and biological control section.

Fig. 2.—Check experimental pond in right foreground, showing floating mats of algae as compared to clear pond on left containing five pairs of *Tilapia mossambica*. The fish required less than a week to clean-up the pond (one of three replicates).

1960; Twinn 1931). Qureshi and Bay (1969) demonstrated some control results with *Hydra americana* Hymen on *Culex peus* Speiser. In collaboration with Dr. Howard Lenhof of the University of California at Irvine, a comprehensive evaluation of several hydra species in practical mosquito and midge control has been launched. Already we have observed that some species kill more mosquito larvae in a given period of time than others; and that they are differentially tolerant of pH and water mineral content. At low oxygen content or water temperatures, hydra roll-up in compressed shapes that are suitable for direct spray application to problem habitats.

Another invertebrate, the planaria (*Turbellaria*) has demonstrated excellent mosquito control under experimental conditions at Riverside. Planaria are considerably larger than hydra and might be more suited to foraging in densely matted habitats.

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GENERAL OPERATIONAL PROGRAM IN THE DELTA MOSQUITO ABATEMENT DISTRICT

Robert E. Turner

Delta Mosquito Abatement District

1737 West Houston Avenue, Visalia, California 93277

The Delta Mosquito Abatement District was formed in 1922 with the primary goal of reducing the serious malaria problem in the Visalia area. Originally it was approximately sixteen square miles in size and embraced the City of Visalia and its immediate suburbs. Early program efforts consisted of applying oil to the local sloughs and swampy areas and to some degree draining and filling them. Together with developing agricultural practices of filling and land leveling, the District was able, in the ensuing ten to twenty years, to reduce the malaria incidence to a negligible level. During this period it became obvious that other pest and disease-transmitting mosquitoes would make an effective program impossible unless the District was expanded considerably. As a result, in the period just following World War II, the District annexed contiguous areas and expanded to its present size of some 712 square miles. It was during this period that modern day insecticides became available and together with increased knowledge of mosquito biology, a practical control program became possible.

Today's program in the Delta MAD consists of a one man, one Jeep per zone philosophy. We employ thirteen permanent inspector-operators and back them up with all the supportive services and equipment that seems desirable. The operator is charged with the responsibility of developing the program in his zone including mapping and recording sources, the inspection and treatment of those sources during the breeding season, and consolidation of records at season's end. Other winter activities include maintenance and overhaul of District vehicles and equipment, building and grounds upkeep, the updating of maps and recording of crops plus the taking of accrued vacations.

During the peak period of mosquito development our basic crew is supplemented by the addition of approximately 22 senior high school and college men. At this time our permanent inspector-operators' responsibilities are generally reduced to the control of the pasture mosquito (*Aedes ni-*

gromaculis), the encephalitis mosquito (*Culex tarsalis*), and the flood water mosquito (*Aedes vexans*). The tree hole mosquito (*Aedes sierrensis*) is a severe pest in the early season and is controlled by airplane adulticiding the larger source areas and some tree surgery by the owner on a smaller scale. The summer men assume the job of handling the house mosquito (*Culex quinquefasciatus*) and other mosquitoes of lesser importance, the foul water *Culex peus*, the *Anopheles*, and the red bodied *Culex erythrothorax*.

The job assignments of these supplemental summer crew men have evolved during several years to a fairly set pattern. The District is divided into seven zones, independent of our permanent control zones, and one man is made responsible for the inspection and treatment of all house mosquito sources in a zone. He is trained to follow this pattern: first eliminate the source if possible. If this cannot be done, modify the source by the planting of fish, removal of weeds or making any other environmental change that will discourage mosquito production. If neither of these practices is possible he will treat the source with the appropriate material. Where contamination by insecticidal treatment is undesirable, he will use a surfactant or, under some circumstances, oil. The source records he works with are the result of years of premise by premise survey and are kept current by continual re-survey by another group of these summer men. Two men take care of the treatment of all the dairy drain sumps on a twice weekly basis, and one man, driving a right-hand drive Jeep, treats all the catch basins, storm drains, and sewage lagoons in the District. We assign one man as a mechanic's helper and we have one man, called a special problems technician, who trouble shoots all other situations needing attention. Our District has for several years been involved in the study of several species of flies of local importance and two of our summer men work with the manager-entomologist in developing this program.

Earlier in this presentation it was noted that supportive services were provided our field men as needed. The District owns one Piper Pawnee "235" and employs a full-time pilot who works directly with the inspector-operators on a daily treatment schedule. Routine weed control is performed as needed on sewage ponds and dairy drain lagoons by oiling and burning during the season and supplemented by the application of soil sterilants in the fall. A constant flow of information is passed to the source reduction unit of our program which in turn engineers and constructs the desirable installations.

We feel we have the knowledge, the ability and the equipment to avoid the development of general, widespread populations of any mosquito species so long as we have available an effective insecticide. Daily assessment of service requests, leg counts in pasture source areas, resting house mosquito adult counts, and immediate post treatment records together with fluid manpower assignment practices, permit us to identify and contain most population increases on a relatively localized level. How much effect the development of resistance to available larvicides may have we cannot foretell, but it is reasonable to presume that some modification of this program will be indicated soon and we're hoping to be ready.

Mention should be made in closing that the District is cognizant of a need it can fill in the study and program development for the control of other public pests, and with this in mind has inaugurated studies on the flies, midges and gnats of local importance.

FUTURE ROLE OF OPERATIONAL PERSONNEL

Albert H. Thompson
Orange County Mosquito Abatement District
Post Office Box 87, Santa Ana, California 92702

In my introduction to the future role of operational personnel in mosquito control work, I will have to rely on many past years of spraying operations. I am sure that most of you are familiar with Orange County and its change from an orange-producing, dairy-farming, chicken-ranching center to the fastest growing population center in all of the western United States. During the past 20 years the population has increased over seven times to one and one-half million people.

In describing the role of the operational personnel of the future I will have to say that the present operator is a technician when compared to the operator of the 1940's. Mosquito control, especially in urban areas, still depends on the repetitive use of pesticides and their continued use will be required in the foreseeable future. The use of modern pesticides requires a thorough knowledge of their limitations. The modern operator must be well trained and experienced in their application. He must be responsible in making decisions in the field on where, when and how they are to be applied. The future role of the mosquito control operator will be to make use of all known techniques to prevent mosquito breeding by use of natural and biological techniques and by water management methods. The most important function of the operator of the future will be to meet the public in the field and, through cooperation and education, prevent the existence of a public nuisance.

Orange County Mosquito Abatement District has constantly strived to maintain an up-to-date record and mapping system of all field functions performed by each operator. In addition to spraying and inspection, the present day operator must have an extensive knowledge of records management. Precise mapping of all mosquito breeding sources and accurate recording of all control operations will be required of the operator. As urban areas develop, the mosquito breeding sources become much smaller but more numerous and much more difficult to locate, inspect and keep under control.

The function of the present and future operator will require some degree of mechanics as he will be called upon to operate many types of spraying and inspection equipment. Orange County Mosquito Abatement District has upgraded its mosquito abatement program by developing highly refined equipment for applying pesticides by spraying, injection and granulating methods. To be able to meter the flow of pesticides, positive control of the equipment that is being operated requires constant training and upgrading of operational personnel.

Today's operator must be an excellent driver as he is constantly in traffic and will be required to drive in all types of conditions, from fast freeway or expressway traffic to neighborhood inspection and two lane farm roads. Orange County Mosquito Abatement District has constantly monitored its driving program. Speed limits are set and maintained by operational personnel.

The seasonal operator requirements have increased throughout the years. A program to interview, test, select and train seasonal operators for specialized jobs will be required to meet future operational needs and standards. On-the-job training has proved to be very important and must be provided by the experienced permanent operators and supervisors. In addition to the seasonal spray operators, our District has taken further steps in public education by the use of residential inspection teams for house-to-house surveillance, inspection and treatment.

In closing I would like to say that the operational personnel now and in the future have the most important role in mosquito abatement programs and it is up to the operator to prove that he is capable of doing this job.

THE ROLE OF FIELD PERSONNEL IN THE COMING ERA OF LAND AND WATER MANAGEMENT FOR MOSQUITO PREVENTION

Harley L. Natvig

California State Department of Public Health

Bureau of Vector Control and Solid Waste Management

Office Building No. 9, 744 P Street, Sacramento, California 95814

Mosquito control in California has seen many changes in the last several years, most of them directly attributable to the insecticide resistance dilemma. Increased emphasis on source reduction or mosquito prevention is the most visible change taking place in local mosquito control agencies. Source reduction techniques have always been used to some extent in mosquito control, but most control has been accomplished by using insecticides. What then is the outlook for these agencies in the coming years? We must first assume that the move toward source reduction is a genuine effort and that the control agencies will really try for results.

It appears that all control agencies must develop procedures for a more functional documentation of mosquito sources. The present approach to documentation is inadequate in most cases. The vastness of such a program will require the use of operational personnel to gather and submit much of the input data for the program.

Source reduction will require many more man hours assigned to making public contacts, problem analysis and concrete proposals and recommendations. In the past, source reduction usually meant that the manager and source reduction specialist were the only ones involved and they were solely responsible for this program. In future years, they will need help to achieve their objectives. That is why we must begin to rely on the operators. The operator's role will increase as the rate of change toward source reduction quickens. It will not be enough just to spray in the future; operators must accept more responsibility for promoting the use of source reduction techniques.

Probably the most important responsibility of the operator in his future role will be his effective communication with the farmer or owner. Most operators have contact with the owner and presently communicate with him, but the future role will be more of an educational one. The operator must be able to explain the various aspects of mosquito production. He must have a sound working knowledge of irrigation, drainage and general farming practices in order to communicate with farmers effectively.

Operators assigned to urban areas must take a similar approach. Communication with urban dwellers again is of paramount importance. A thorough knowledge of mosquito sources and their causes is required before operators can inform and educate people. Urban sources are usually small compared with sources associated with irrigated agriculture. Nevertheless, they can be of great importance because of the proximity to homes and public places.

Operators will be expected to spend more time analyzing mosquito problems with particular emphasis directed toward areas where resistance to insecticides is present. They should become more familiar with the use of aerial photographs as a tool. Many times, it is easier to visualize a problem area from an aerial photograph than from ground observations. Operators should be able to prepare sketches to larger scale sizes from aerial photographs. Important information and field data such as mosquito production areas can be plotted on sketches developed from aerials. These sketches are particularly valuable as visual aids when conversing with the owners. Operators will also be expected to familiarize themselves with the basic concepts of determining existing field topography and features. They may, for example, be expected to operate a leveling instrument. Extensive data collection is a prerequisite before the manager and source reduction specialist can make an in-depth study of the problem. A comprehensive study will be the basis for development of definitive proposals and recommendations.

In areas of agricultural concern, operators should have knowledge of the costs and the economic ramifications associated with land improvements and renovations. Some important costs are those identified with land leveling, excavation for ditches, installing pipeline, lining irrigation ditches and establishing permanent vegetative cover. Much of this information is no doubt available in the mosquito abatement agency office from the source reduction specialist or manager. If not, it can be obtained from local industry representatives or from other government agencies. Knowledge of present crop worth and commodity prices can be helpful when communicating with farmers. Such knowledge might include the economics of pasture and other forage crops, or possibly the local prices for milk and beef cattle. Much of this information is also available at the abatement agency or can easily be obtained.

No one expects the operator to be an expert in these matters, but familiarity with them will be of great assistance. One of the more important services the operator of the future will provide will be that of giving reliable directions on who one should turn to for more specific information.

Types of equipment and equipment capabilities should be an area of concern for operators in the future. Effective communication with property owners will depend to a great extent on knowledge of basic equipment. This includes equipment used in such works as land leveling, constructing irrigation and drainage ditches, installing pipeline and lining irrigation ditches.

Construction of drainage ditches is very basic in source reduction work and usually the first equipment that comes to mind is the back hoe. Back hoes are good; but they have limited utility. Construction of new ditches can be accomplished much more efficiently with single wing plows, graders or motor patrols and self-propelled dtiching machines. For cleaning ditches, much better control can be achieved using a Gradall with a telescoping arm.

Operators will be expected to know the advantages and limitations of various equipment used in land renovation. This will require some study and training for most operators, although some operators may be familiar with and possibly have even operated some of the equipment. Effective land and water management depends on proper equipment and its efficient operation.

Operators are often the front-line staff representing the control agency and their talents should be fully utilized. Appropriate consideration should be given to their judgment concerning measures which may be used to solve mosquito source problems.

The operators can supply some of the most valuable information to be used in solving one of California's major environmental problems. The burden will be heavy, the task will not be easy, and this new role will not be accomplished immediately. But, it is inevitable that these changes will come. The district managers will have an increasing responsibility to see that all sound staff recommendations are implemented. An important new dimension in mosquito control will be added when operators begin to share the responsibility for developing control recommendations and, at the same time, begin to witness their achievements in this vital new role.

INFLUENCES OF OTHER INTERESTS ON MOSQUITO CONTROL IN CALIFORNIA

Marvin C. Kramer
California State Department of Public Health
Bureau of Vector Control and Solid Waste Management
Office Building No. 9, 744 P Street, Sacramento, California 95814

Laws recently enacted in California and a proposed constitutional amendment relating to tax limitations could have significant influence upon mosquito control programs in California. The laws are the Porter-Cologne Water Quality Act; AB 2870 of the 1971 session, which is now in Chapter 1241 of the Government Code; federal law PL 91-190, the National Environmental Policy Act of 1969; and AB 2945, which is now in Division 13 of the Public Resources Code. The proposed constitutional amendment is the Watson tax initiative.

The Porter-Cologne Water Quality Act created a board of full-time, paid members, gave it great powers for establishment of criteria and for enforcement, and prescribed stiff penalties for non-compliance. Following are some excerpts from the Act and related water code sections:

Division 1, Chapter 2, Article 3, Section 174.

"The Legislature hereby finds and declares that . . . it is necessary to establish a control board which shall exercise the adjudicatory and regulatory functions of the state . . ."

Division 7, Chapter 1, Section 13000.

". . . The Legislature further finds and declares that activities and factors which may affect the quality of the waters of the state shall be regulated to attain the highest water quality which is reasonable, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible . . ."

"13001. It is the intent of the Legislature that the state board and each regional board shall be the principal state agencies with primary responsibility for coordination and control of water quality."

Division 7, Chapter 3, Article 4, Section 13165.

"The state board may require any state or local agency to investigate and report on any technical factors involved in water quality control; . . ."

Division 7, Chapter 4, Article 2, Section 13225.

"Each regional board, with respect to its region, shall: (a) obtain coordinated action in water quality control including the prevention and abatement of water pollution and nuisance. . . (d) request enforcement by appropriate federal, state and local agencies of their respective water quality control laws . . ."

Division 7, Chapter 4, Article 4, Section 13260.

"(a) Any person discharging waste or proposing to discharge waste . . . shall file with the regional board of that region a report of the discharge . . .

"13263 (a) The regional board, after any necessary hearing, shall prescribe requirements as to the nature of any proposed discharge, existing discharge, or material change therein, . . . (b) A regional board . . . need not authorize the utilization of the full waste assimilation capacities of the receiving waters. (c) The requirements may contain a time schedule, . . . (d) The board may prescribe requirements although no discharge report has been filed. (e) Upon application by any affected person or on its own motion, the regional board may review and revise requirements . . ."

Division 7, Chapter 5, Article 1, Section 13000.

"Whenever a regional board finds that a discharge of waste is taking place or threatening to take place that violates or will violate requirements . . . The board may require the discharger to submit for approval . . . a detailed time schedule of specific actions the discharger shall take in order to correct or prevent a violation of requirements."

"13301. When a regional board finds that a discharge of waste is taking place or threatening to take place in violation of requirements . . . the board may issue an order to cease and desist . . .

"13304. (a) Any person who discharges waste into the waters of this state in violation of any waste discharge requirement or other order issued by a regional board, or who intentionally or negligently causes or permits any waste to be discharged or deposited where it is, or probably will be, discharged into the waters of the state and creates, or threatens to create, a condition of pollution or nuisance, shall upon order of the regional board clean up such waste or abate the effects thereof . . . (b) If such waste is cleaned up or the effects thereof abated by any governmental agency after issuance of a regional board cleanup or abatement order, such person shall be liable to that governmental agency to the extent of the reasonable costs actually incurred . . . "

Since passage of the Act the State Board has been involved in the setting of criteria for disposal of agricultural drainage waters. There is a real possibility that such drainage waters will be confined to the property of origin. The ultimate goal is to include all types of agricultural effluent; immediate attention is directed toward wastes from livestock operations, and particularly confined livestock.

We pointed out to the State Board that such action would have many ramifications. Problems are best resolved when they are exposed early, are considered by all interested agencies, and when there is good rapport among the agencies. We took the initiative in inviting representatives of the agencies that could be affected to meetings in Sacramento.

Agencies that responded and had representatives present were California State Water Resources Control Board, Central Valley Regional Water Quality Control Board, California Department of Water Resources, Agricultural Extension Service, California Mosquito Control Association, East Side Mosquito Abatement District, Irrigation Districts Association of California, Modesto Irrigation District, California Division of Soil Conservation, Agricultural Stabilization and Conservation Service, U. S. Soil Conservation Service, and the Bureau of Vector Control and Solid Waste Management.

These were exploratory discussions of the interrelationships involved if water quality requirements are to be placed on agricultural drainage waters. These meetings were conceived as a means for developing a workable plan for water management that will respect the needs of all.

Richard F. Peters, Chief, Bureau of Vector Control and Solid Waste Management, brought into focus the present crisis in mosquito control and outlined the evolution of mosquito control in California.

Conferees were attentive and sincere. We know that they listened because there were subsequent releases to all of the irrigation districts, e.g., about the crisis and the need for water management, and the Agricultural Stabilization and Conservation Service made money immediately available, with a high priority, for practices that will be favorable to mosquito suppression.

Another outgrowth from these meetings was an invitation from the State Water Resources Control Board to have a representative on its Agricultural Advisory Committee. We have been participating in this committee, and now have a voice in the formulation of criteria.

AB 2870 of the 1971 legislative session which is now law requires local agency formation commissions to initiate and make studies of existing governmental agencies, and specifies the required content of such studies. LAFCO also is required to determine the sphere of influence of each local governmental agency within the county, and use spheres of influence as the basis for decisions on proposals and recommended governmental reorganizations. LAFCO can, to a large extent, control the destinies of local governmental agencies. It has never been more important for local agencies, already under the scrutiny of organizations such as taxpayers' associations, to conduct a precision operation, to maintain accurate records, and to make LAFCO and the public aware of services performed and protection provided. Judgments of the value of the local agency and decisions affecting its future will be made within the county.

Federal and state laws require water project construction agencies to obtain statements describing the environmental impact of their proposed projects from organizations that could be affected. The federal law covers all projects that receive federal funding. The state law supplements the federal law to cover the projects that do not receive federal funding. Builders of projects are apprehensive. They dislike the onus of having to solicit comments from all interested agencies and the preparation of environmental impact statements. They are taking great care to be thorough and accurate because they want to preclude having issues resolved or decisions made by the courts. Environmentalists have the ear and the sympathy of the public, a shift of public opinion has been reflected in the courts, and class action suits now are permissible in the courts, whereas in former days one had to sustain damage to have standing in the courts.

The Bureau of Vector Control and Solid Waste Management has for several years had cooperative agreements with federal, state, and local agencies for review of and comment upon the plans and designs of new projects, and have had mosquito prevention measures incorporated in the projects. This will be continued under the new formalized procedure.

After unsuccessful attempts in 1971 to stimulate the introduction of legislation that would limit the amount of property tax in California, the assessor of Los Angeles County, Philip E. Watson, is proposing a constitutional amendment through the vehicle of an initiative. The amendment, among other things, would place an absolute limit on property taxes of 1.75 percent of the market value for all purposes other than for the payment of debts or liabilities. All intracounty special districts would be allowed 50 cents for each $100 assessed valuation, and all intercounty special districts would be allowed the same amount. Boards of Supervisors would apportion the aggregate 50 cent maximum tax rate amoung all special districts.

State Legislative Analyst A. Alan Post has estimated that the amendment would be about $700 million short of meeting present tax needs even though the amendment would provide for increases in taxes on sales, cigarettes, distilled spirits, and banks and corporations, and would impose new taxes on income of insurance companies and severance of all minerals.

The greatest threat to special districts of the proposed amendment is its failure to replace local government revenues which would be lost. If the proposed amendment reaches the ballot and is approved in June, it would become effective July 1, and this would necessitate immediate widespread changes at all governmental levels. Steve Dykes of the Assembly Revenue and Taxation Committee staff observed that set rates foretell the end of independent local government.

It is in the interest of every mosquito control agency in California and the public at large to be thoroughly familiar with the provisions of this measure and to assess the nature and extent of its effects.

FIELD OBSERVATION ON OVIPOSITION SITE PREFERENCE OF THE PASTURE MOSQUITO, *AEDES NIGROMACULIS*

Takeshi Miura and R. M. Takahashi

University of California

Mosquito Control Research Laboratory, 5545 East Shields Avenue, Fresno, California 93727

ABSTRACT

The pasture mosquito, *Aedes nigromaculis* (Ludlow), females oviposited in clumps of bunch-forming grasses in irrigated pastures, especially in clumps growing in temporary pool areas. Within a given clump, most eggs were deposited in the peripheral areas and near the surface of the ground. In pastures where bermuda-type grasses were dominant, females laid eggs in depressions with spike rushes or in dense bermuda patches.

STUDIES OF SPIDER PREDATION ON *AEDES DORSALIS* (MEIGEN) IN A SALT MARSH

Richard Garcia[1] and Evert I. Schlinger[2]

University of California

Spiders hold the unique position of being the only large class of arthropods which are entirely predatory in nature. The vast majority of species depend on insects as their chief source of nourishment. Despite the fact that their predatory nature is well known, quantitative studies on their role as regulators of insect pest populations is not well understood, relative to their potential importance in governing these species.

Reports of spider predation on mosquitoes are scattered in the literature and usually note only the species and sometimes the number of mosquitoes trapped in the webs of different spider species (reviewed by Hinman, 1934; Christophers, 1960). Recently, however, several European investigators have been evaluating quantitatively the role of spiders in the natural regulation of mosquitoes in forest ecosystems. These workers have noted that several web-building species were capable of reducing adult mosquito populations by over 50% in certain studies (Luczak, 1968; Dabrowska–Prot et al. 1968a; and Dabrowska–Prot et al. 1968b).

Recent observations on *Aedes dorsalis* in a Petaluma marsh indicate that the small hunting spider *Pardosa sternalis* (Thorell) may be an effective predator on this mosquito. Bishop and Hart (1931) first reported this spider capturing *Aedes* mosquitoes in Colorado. They noted spiders feeding on adults, pupae and larvae; however, they did not identify the mosquito species. Except for these preliminary notes and some laboratory observations no further work was reported.

As mosquito abatement moves into the area of integrated control it becomes essential to investigate the mortality factors produced by natural enemies such as spiders. It is anticipated that an understanding of these mortality mechanisms may allow us to use them in a beneficial manner to complement currently employed control techniques. It is within the concept of integrated control that this preliminary investigation of the relationship of salt marsh spiders and mosquitoes is reported.

METHODS AND MATERIALS.—These observations were made in an area of the Petaluma salt marsh approximately four miles north of Novato and one mile east of Highway 101 in Marin County. The area consists of an extensive stand of almost pure pickleweed (*Salicornia* sp.). The vegetation is interrupted by occasional potholes and drainage canals. The smaller potholes which are filled periodically by high tidal action form the principal breeding sites for *A. dorsalis* in this marsh.

Predatory behavior of *P. sternalis* was observed directly in the field as well as in the laboratory. Standard five gallon glass aquaria with a layer of dried pickleweed on the floor and an 18 mesh screen cover were used as terraria to contain the spiders in the laboratory. *Aedes aegypti* (Linnaeus) larvae and pupae were offered as food in petri dishes partially filled with water.

Spider populations in the marsh were estimated from samples taken with a D-Vac® vacuum insect net model 1-A. The sampling technique employed was essentially the same as described by Dietrick et al. (1960).

DISTRIBUTION AND LIFE CYCLE.—*Pardosa sternalis* is widely abundant west of the Great Plains from Canada to Mexico. It occurs from sea level to 9000 feet and is found commonly in salt marshes and meadows usually in close association with free water. Mating usually occurs in late winter or spring followed soon after by egg laying. The egg cluster is carried by the female until hatching takes place after approximately two weeks. This population matures in the late summer and fall and depending on climatic conditions may produce a second generation before winter.

RESULTS AND DISCUSSION.—Field observations indicate that *P. sternalis* uses movement of prey as the primary stimulus to attack. Superficially, *A. dorsalis* appears most vulnerable when it is emerging from its pupal skin; but because this process is gradual it does not readily attract the spiders' attention. Predation on mosquitoes in the salt marsh has thus far been observed only after the individual has completely emerged. Generally the teneral adult remains a short time on the skin then walks across the water surface and climbs the ascending stalks of *Salicornia* at the edges of the pothole. It is during this movement across the water or while resting on the *Salicornia* that the spiders attack the mosquitoes.

Spiders are typically more numerous on the water surface when the air is completely calm. Moderate wind velocities tend to discourage their activities on the water surface. They remain however, relatively active at the edges of the potholes.

After capturing its prey on the water surface the spider moves back to the confines of the vegetation to devour its food, which usually requires several minutes. The pedipalps are the major appendages used to capture prey as well as to hold and manipulate it during the process of feeding.

Spiders were not observed capturing larvae or pupae of *A. dorsalis* in the field. However, obvious attempts at capturing these aquatic stages were seen. In the laboratory, spiders (fall populations) fed readily on larvae and pupae which were placed in water-filled petri dish bottoms placed on the floor of the terraria. In one test, 18 out of 24 larvae and pupae were captured and consumed by eight adult and immature spiders during a 10-day period. Of the six remaining individuals three were captured as adults shortly after emergence. Both field and laboratory evidence suggest that the spiders use vision and possibly vibrations to locate and capture their aquatic prey at the waters surface. After moving near to its food the spider grasps the aquatic stage with its pedipalps and quickly extracts it from the water.

[1]Division of Biological Control, 1050 San Pablo Avenue, Albany, California 94706.

[2]Division of Entomology, 201 Wellman Hall, Berkeley, California 94720.

Field observations on the food habits of this spider indicate that it probably feeds on the most abundant aquatic insects present in the brackish pools. This would of course vary with the seasonal occurrence of the prey as well as with the ease of capture of the particular organism. In addition to *A. dorsalis*, two other species of insects have been observed being captured frequently on the water surface. These were the brine fly, *Ephydra riparia* Fallen, an exclusively aquatic insect (Usinger 1963), and the small brackish water corixid, *Trichocorixa reticulata* (Guerin-Meneville). Much of the activity of the brine fly adults is spent on the water surface and it was relatively common during observation periods in the fall months. The timid nature of this fly makes successful captures by the spiders difficult. Observations on ten spiders indicated that a successful capture required about 20 attempts. During two successive observation periods the small corixid was the major source of food, while on two other occasions *A. dorsalis* was the prey taken most often. During the observation periods when corixids were most ofton captured the ephydrid fly and the corixid were the only abundant species. Apparently the corixids were captured as they came to the surface to obtain air or leave the pool.

Table 1 demonstrates the wide diversity of spiders present in the salt marsh. The nine families collected from the marsh are each represented by several species. Estimates from D-Vac sweep collections indicate that there are between one million and one and one half million spiders per acre during the fall. Unfortunately little is known about their food habits; however, their large numbers and wide diversity lead one to suspect that their role in regulating insect populations including *A. dorsalis* is important.

Table 2 shows the abundance of *P. sternalis* and its relationship to the brackish water potholes. Variations in numbers occur between populations at different potholes, but these have not been evaluated at this time. The larger number of spiders near the pools contrasted to the lower number in the open drier part of the marsh during the fall probably reflects the water-oriented hunting behavior of this species. The winter populations declined precipitously and *Pardosa* was then more common in the open drier parts of the marsh. Cold temperatures are the probable cause for the population decline and the change in distribution. Areas near the potholes are open and less protective then the dense continuous stands of pickleweed in the drier parts of the marsh.

In summary we believe that these spiders are probably important natural enemies of mosquitoes, particularly in salt marshes, because of their large numbers and close association with water. Studies planned for the spring and summer when *A. dorsalis* is more abundant should shed more light on the overall importance of *P. sternalis* and the other spider species as natural enemies of this mosquito.

Table 1.—Families of spiders associated with Petaluma Salt Marsh 1971*

		Running
Lycosidae	–	Mainly soil and vegetation and sometimes water surfaces
Clubionidae	–	Mainly vegetation
Gnaphosidae	–	Soil and in soil cracks
Oxyopidae	–	Mainly tips of vegetation
Thomisidae	–	Mainly on vegetation
		Jumping
Salticidae	–	Mainly on vegetation
		Web-Building
Araneidae	–	Webs constructed
Therididae	–	in
Micryphantidae	–	vegetation

*Collected by D-Vac sweeper.

Table 2.—Fall and winter abundance and location of *Pardosa sternalis* in the Petaluma Salt Marsh – 1971[a]

	Near Pothole[b]		Away From Pothole[c]	
	Adults	Immatures	Adults	Immatures
Fall	50	294	12	176
Winter	0	15	4	33

[a]Ave. number per 50 sq. ft. Based on sampling 300 sq. ft.

[b]Within three ft. of pothole edge.

[c]Farther than ten ft. from pothole.

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THE THEORETICAL ASPECTS OF A LARGE–SCALE FIELD TEST OF RICE FIELD MOSQUITO CONTROL[1]

James B. Hoy[2] and Allan G. O'Berg[3,4]

Field tests in 1969 and 1970 showed that *Gambusia affinis* (Baird and Girard) can give satisfactory control of rice field mosquitoes in California (Hoy and Reed, 1970, 1971; Hoy et al. 1971).

During 1971 the Sutter-Yuba Mosquito Abatement District and the Entomology Research Division of the USDA conducted a large-scale field test of three alternate methods of rice field mosquito control (Hoy et al. 1972). The study involved 72 rice fields in the Sutter Basin, in which about 45 percent of the land is used to grow rice. The fields were equally divided among four treatments: (1) fields stocked with 0.6 lb of fish per acre, (2) fields stocked with 0.2 lb of fish per acre, (3) fields treated once with 0.0125 lb of chlorpyrifos (Dursban®) per acre, and (4) experimental control fields. Six-tenths of a pound of fish is approximately 300 mature females. The mosquito production of each field was evaluated during late June, late July and late August. Two evaluators each took equal sized samples from both the high and low ends of each field. During the first two evaluations 80 dips per field were taken and during the last evaluation 120 dips per field were taken.

In August, fish populations were measured by placing 12 traps in each of the 72 fields.

The results of the evaluation of mosquito production are illustrated in Figure 1. Shown month by month are the numbers of specimens per dip (see the right-hand scale) and also the mean number of specimens, in terms of the transformation used in the analyses of variance that were performed (see the left-hand scale). We should point out that transformation of the raw data to the log (N + 1) is a conservative way of handling the data, in that fields that have gone completely out of control do not contribute as much to the mean values as when the data are untransformed.

The mean values that are significantly different from other values are bracketed to indicate the range representing the 5% least significant difference.

The results may be summarized as follows: (a) During June, the fields stocked with 0.2 lb of fish per acre produced significantly more mosquitoes than the other treatments, (b) During July, the fields that had been treated once with chlorpyrifos produced significantly more mosquitoes than either the control fields or the fields stocked with 0.6 lb of fish per acre, (c) During August, the fields treated only once with chlorpyrifos produced significantly more mosquitoes than the controls of either treatment where fish were stocked. Also, regarding the distribution of larvae and pupae, during August, there was a significant but not a large difference in mosquito production when the high versus the low ends of the fields were compared, with greater production in the low ends.

Evaluation of the various fish populations showed that the biomasses of fish were very similar by August, regardless of whether 0.2 or 0.6 lb per acre had been stocked. However, the higher stocking rate yielded a high number of fish per field. Of the 36 fields that were not stocked with fish only four yielded fish. One field appeared to have been accidentally stocked, whereas the other three had only small numbers of fish. Since there was no proof of the accidental stocking, the conservative method of analysis, i. e., retaining the mosquito evaluation data from the odd field in the same treatment category was observed.

In June we were surprised by how many mosquito specimens we found in the fields stocked with 0.2 lb of fish per acre. This was in contrast to quite low numbers of speci-

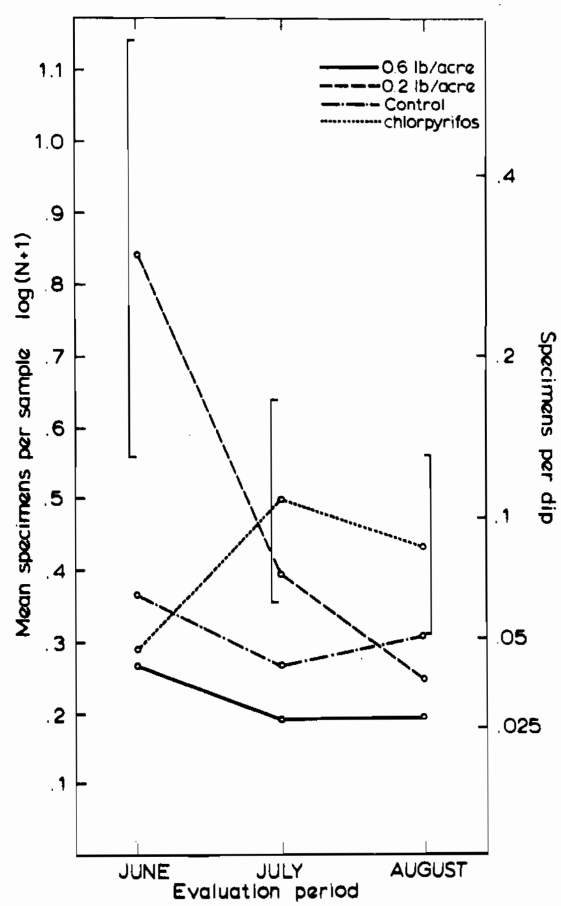

Fig. 1.–Numbers of specimens found in rice fields during three evaluation periods. Each treatment was replicated 18 times and four subsamples were taken within each replicate; therefore, each point represents 72 subsamples. A total of 20,160 dips is thus represented (from Hoy et al. 1972).

[1]Mention of a pesticide or a proprietary product in this paper does not constitute a recommendation or an endorsement of the product by the U. S. Department of Agriculture.

[2]Entomology Research Division, Agriculture Research Service, United States Department of Agriculture, 5544 Air Terminal Drive, Fresno, California 93727.

[3]Sutter-Yuba Mosquito Abatement District, 925 Market Street, Yuba City, California 95991.

[4]Present address: Yuba College, N. Beale Road and Linda Avenue, Marysville, California 95901.

mens in the experimental control fields. Note (Fig. 1) the low number of specimens per dip.

The great resurgence of the mosquito populations in the chlorpyrifos-treated fields during July (and August) was not especially surprising. Pest resurgence is a phenomenon well recognized in agricultural entomology circles, where continued interest in a specific pest population is generated by the value of the crop originally under attack. The control fields were lower in mosquito production in July than in June. Following the July evaluation we independently arrived at an explanation for the high mosquito production in the fields stocked at 0.2 lb of fish per acre. The key was the low mosquito production in the undisturbed (control) fields. To have such low production in the absence of either chlorpyrifos or fish called for a natural control mechanism that could be disrupted by either chemical control or a fish population of intermediate size. Obviously a large fish population was effective for control and a very low fish population would be ineffective as a disruptive force. The choice of 0.2 lb of fish per acre may have come close to the "optimum" rate for demonstration of a biologically triggered disruption. The transitory nature of a biological disruption contrasts with the chemically triggered disruption that we observed in July and August. Once the fish population passed the intermediate point, they cured the outbreak that they had induced. Contrariwise, the chlorpyrifos-induced outbreak continued through August.

Both types of disruption must be avoided at all costs. Certainly any control method that risks driving mosquito populations higher than if no treatment had been applied is a bad method. These results emphasize the need for a better understanding of the relationships between predators and mosquitoes in the rice fields.

ACKNOWLEDGMENTS.–We wish to acknowledge the help of the entire staff of the Sutter-Yuba Mosquito Abatement District who contributed greatly to this study, particularly Stanley Moore and Gerald Ruff who participated in every phase of the stocking operation. The technical support of Terrell Tucker and Robert Stout during the evaluation phase of the experiment is gratefully acknowledged. Eugene E. Kauffman, Manager-Entomologist, Sutter-Yuba MAD deserves special recognition for his contributions to this study.

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POPULATIONS OF *GAMBUSIA AFFINIS* IN A CLINE OF OXIDATION PONDS

J. L. Fisher[1], R. K. Washino[1] and J. Fowler[2]

Studies were initiated to evaluate sewage oxidation ponds as potential overwintering and/or breeding sites for *Gambusia affinis*. Previous attempts to utilize sewage ponds for these purposes produced mixed results. The proximity of sewage oxidation ponds to prime mosquito problem areas in the Sacramento Valley of California (i.e., rice fields) would enable a substantial reduction in time and cost for most control agencies to utilize fish in their control operation. The purpose of this report is to summarize the preliminary results obtained.

The ponds selected for observation were located approximately two miles east of the community which they serve (Woodland). Sewage treatment consisted of coarse screening and simultaneous distribution (parallel) of the sewage into sets of four ponds. For the purpose of this study, this parallel design in one set of four ponds was changed to a series to form a gradient of decreasing organic load from the first pond (A) to the second (B) and to the third and fourth (C). It was anticipated that fish productivity/survival would differ in the four ponds, and that by making a survey of physical, chemical and biological factors in each of the ponds, limiting factor(s) of *G. affinis* populations could be identified. The physical and chemical factors studied were ortho- and polyphosphates, ammonia nitrogen, oxygen, alkalinity, pH and temperature. Biological data included information on the abundance of algae, the major invertebrates and *G. affinis*. Populations of invertebrates were further related to fish populations by examining fish gut samples at bi-weekly intervals. The fish population was sampled periodically by seining a 30-foot-wide area across the entire length of each pond. On February 9 and 16, 1971, a total of 60,000 fish were planted in each of the ponds. Within a month no fish were observed in pond A. Fish populations in ponds B and C increased until July 15 when a mass die-off of gravid females was observed in pond B. No die-off was observed in pond C at that time.

Almost all of the organisms in the ponds exhibited wide fluctuations in numbers throughout the sampling period. Dominant algae in pond A were *Scenedesmus*, *Chlorella* and *Chlamydomonas*. In pond B, the same three algae were dominant, but less abundant than in pond A. Pennate diatoms occurred in greater numbers in pond B and were the dominant alga in pond C. The algae that were dominant in ponds A and B were of minor significance in pond C.

Pending a more complete analysis, certain tentative con-

[1]University of California, Department of Entomology, 367 Briggs Hall, Davis, California 95616.

[2]Sacramento-Yolo Mosquito Abatement District, 1650 Silica Avenue, Sacramento, California 95815.

clusions were made. Oxidation ponds showed a potential for producing *G. affinis* when the ponds were (1) arranged in series with the objective of utilizing the more stable terminal ponds, and (2) designed to maintain certain minimal detention time of sewage in each pond to provide a satisfactory gradient or organic load from pond to pond.

ASSOCIATION ANALYSIS OF POND COMMUNITIES

Robert K. Washino
University of California
Department of Entomology, 367 Briggs Hall, Davis, California 95616

Interrelations among the common aquatic insects in a rice field habitat were studied from 4,633 aquatic dipping samples. These samples were collected at weekly, or bi-weekly intervals during 1969-1971 from rice fields in five counties in the Central Valley of California. Over 81 different animals were identified and processed, and from this, 15 of the most common insects were analyzed for significant X^2 association values with *Culex tarsalis* and *Anopheles freeborni.* On the basis of presence and absence data, significant positive association with *C. tarsalis* was commonly seen with (1) mayfly nymphs (*Siphlonurus* sp.), (2) damselfly nymphs, and (3) predaceous diving beetle larvae and adults (*Laccophilus* spp.). Significant associations with *A. freeborni* were with (1) dragonfly nymphs and (2) *Belostoma flumineum/bakeri* nymphs and adults. When coupled with other supportive information, these values are useful in gaining an insight into which aquatic insects may be serving as effective natural predators of mosquito larvae and pupae. These values may also be used to establish indicator species. These indicator species may be useful to ascertain the presence or absence of a mosquito such as *A. freeborni* which is otherwise difficult to sample directly in a rice field habitat. For further analysis of the rice field as a distinct animal community, the presence and absence data for the insects were used to establish X^2 matrices (all possible combinations of species in pairs by year by county). Water boatman (*Corisella* sp.), predaceous diving beetle larvae (*Laccophilus* spp.) and mayfly nymphs (*Siphlonurus* sp.) had the highest association indices (ΣX^2) and were tentatively interpreted as being "critical" in aquatic animal communities in rice field in Northern California.

IDENTIFICATION OF MOSQUITO BLOOD MEALS BY THE HEMOGLOBIN CRYSTALLIZATION METHOD

Robert K. Washino and James G. Else
University of California
Department of Entomology, 367 Briggs Hall, Davis, California 95616

ABSTRACT

Identification of mosquito blood meals was conducted by the method of hemoglobin crystallization. The technique involved crystallizing hemoglobin from blood samples taken from the mosquito midgut, and comparing crystal structure with that of known materials. Distinct crystals have been observed and photographed from blood samples of three species of equids, four species of bovids, six species of rodents, and three species of other mammals.

INTERRELATION BETWEEN WATER DEPTHS AND THE DISTRIBUTION OF *GAMBUSIA AFFINIS* AND IMMATURE *CULEX TARSALIS* IN FRESNO COUNTY RICE FIELDS

D. E. Reed and T. J. Bryant
Fresno Westside Mosquito Abatement District
P. O. Box 125, Firebaugh, California 93622

The relationship of water depth to production of mosquitoes in rice fields was observed by Washino (1964). However, there appears to be a paucity of supportive documentation in the literature on this relationship. Some authors allude to water depths when discussing mosquito larvae distribution in rice fields (Markos, 1951; Gieger & Purdy, 1918).

Gieger and Purdy (1919) note that *Gambusia* are found mainly along the edges of the paddies and paddy inlets, and few fish were observed in mid field (paddy). Washino (1964) supports this view, in part, in studies made of oxygen content of rice waters. Twenty-four hour observations of dissolved oxygen showed the greatest fluctuations in the center of the paddy (Washino, 1964) with the lowest concentration shortly prior to dawn. Movement of *Gambusia* into and out of the center of a paddy could well be attributed to the available oxygen. In preliminary fish trappings made in rice fields (Hoy and O'Grady 1971) there is additional evidence showing preference of *Gambusia* to the edges of the paddies.

Water depth measurements were taken in the course of several studies in the use of *Gambusia affinis* as a control of mosquitoes in rice fields, which were undertaken by the Fresno Westside MAD during the summer of 1971. It is the purpose of this paper to document the relationship of water depth in rice fields and the presence of *C. tarsalis* and/or *G. affinis*.

MATERIALS AND METHODS.–The study area used has been previously described (Hoy and Reed 1971). For the purpose of this study, however, no regard to proximity to populated areas was made. In addition, rice fields used were owned or managed, in the majority, by two large rice growers. Rice fields belonging to these two growers were scattered throughout the study area.

There were 41 rice fields of various sizes stocked with fish. Ten of these fields were stocked at 50 fish to the acre and 31 fields at 100 fish to the acre. Four unstocked and untreated (chemically) rice fields were used as controls.

Rice fields were sampled for mosquito production by making a ten dip transect across the paddy in the sampling area in the manner described by Hoy and Reed (1970, 1971). Ten paddies were sampled in each rice field. Dipper sample contents were concentrated with a hand concentrator in a manner described by Husbands (1969). Mosquito larvae were killed and preserved in 50% isopropyl alcohol for later laboratory identification. Sampling for larvae started July 4 when rice was in early to late tiller and continued to August 20 when rice had reached grain formation.

G. affinis stocking was started on May 14 and concluded on June 4. About 10% of the fish placed into rice fields came from local natural sources. The balance were purchased from a minnow farm. Fish were trapped in the rice fields by using unbaited Gee's improved wire minnow trap. All trappings were done only once during the season within 72 hours of larval sampling and were placed into each field for 24 hours. Traps were located in rice paddies 20 to 25 yards from the edge of the field and into each paddy six to ten feet from edge of borrow pit area. Water depths were measured at the trap location. About 90% of the traps were located on the downwind portion of the field in the shallow (up-stream) area of the paddy.

RESULTS AND DISCUSSION.–Measurements of water depths were divided into five categories: those 2 inches deep or less; 3-4 inches, 5-6 inches, 7-8 inches, and more than 8 inches deep. Although quantitative records were kept for all fields throughout the season only the presence or absence (qualitative) of mosquito larvae –– or *Gambusia* are used in this report.

Results show that as water depth increases the percent of traps containg fish also increased from about 70% to 100% and lends support to the observations made by Gieger and Purdy (1919). Conversely, in these same paddies, the presence of *C. tarsalis* dropped from 36% in the shallow paddies to zero in deep paddies. In evaluating the effectiveness of *Gambusia* for mosquito control in rice, care must be taken to not assume that increased presence of fish will mean a reduced presence of *C. tarsalis* on the basis of these results without considering the use of controls (unstocked and untreated fields). Without the use of a comparison offered by a control the results thus far may lead to the assumption that the greater presence of *G. affinis* produced a decreased presence of *C. tarsalis* (Figure 1). When controls are included in the analysis there is virtually no difference noted in the presence of *C. tarsalis* in these paddies than in paddies which contained fish. Actual mosquito production in rice is best measured by the presence of fourth instar larvae and pupae. Although there were fewer stations containing fourth instar and pupae, our results show the same trend as does the total collections.

On the basis of the results it can be concluded that chances are very good that a rice field or paddy will produce mosquitoes, when the conditions are favorable, whether or not *Gambusia* are present. In addition, the chances of finding mosquito larvae are increased in the more shallow fields or paddies.

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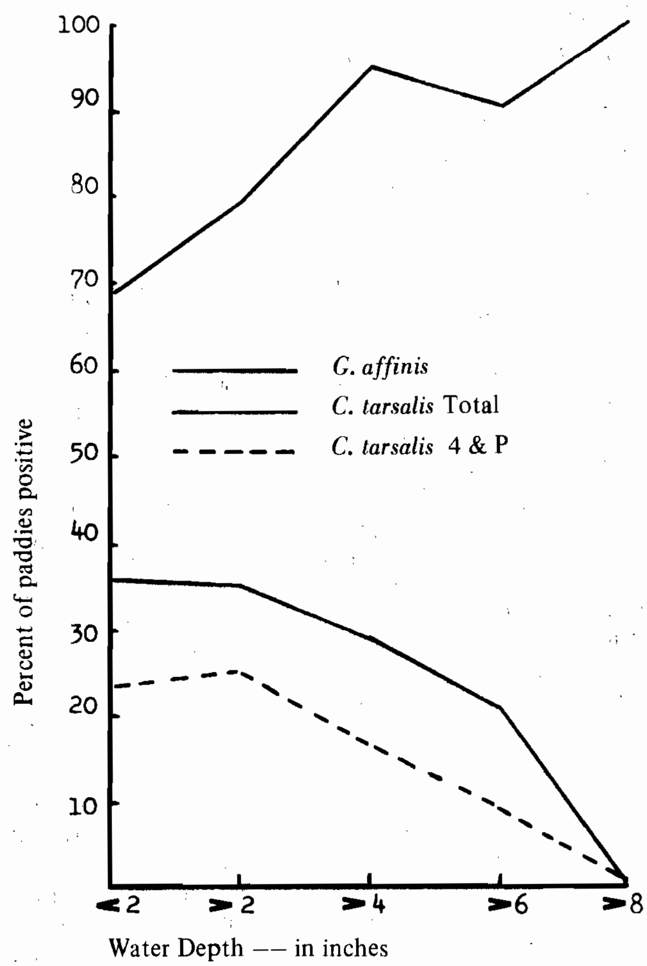

Fig. 1.–Comparison of water depth to presence of *C. tarsalis* and *G. affinis* in the same paddies.

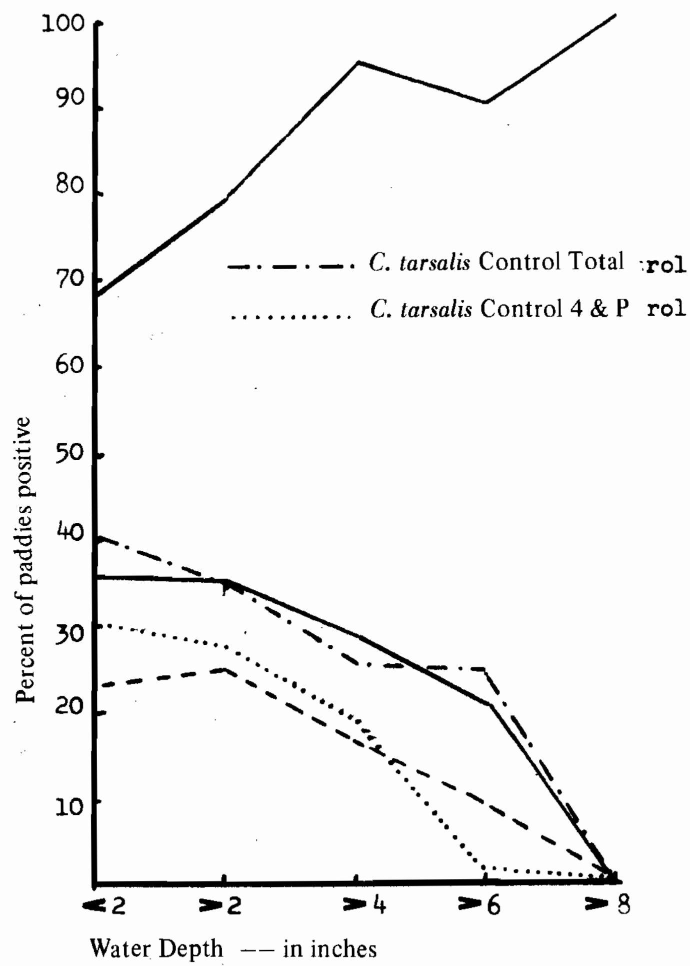

Fig. 2.–Same as Figure 1 — experimental controls are added.

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MINIMUM OXYGEN THRESHOLDS OF *GAMBUSIA AFFINIS* (BAIRD AND GIRARD) AND *POECILIA RETICULATA* PETERS

Robert D. Sjogren
Kern Mosquito Abatement District
P. O. Box 1271, Bakersfield, California 93302

INTRODUCTION.—Of the many water quality parameters which influence the survival of fish in polluted water, dissolved oxygen has received the greatest emphasis. Numerous publications refer to the oxygen requirements of game fish, but little work has been done on the mosquitofish, *Gambusia affinis* (Baird and Girard) or the guppy, *Poecilia reticulata* Peters. Odum and Caldwell (1955) reported *Gambusia affinis holbrooki* survived a constant 0.3 ppm oxygen in an anaerobic fresh water spring where the fish had access to the surface. Reports of random oxygen measurements of field waters made for other purposes occasionally mention the presence of *Gambusia*, but the disjunct nature of such data and the variability in field waters makes meaningful correlation difficult.

The ability of *Gambusia* to adapt to a wide range of water quality has been recognized and put to use by mosquito control workers since an early report by Emerick (1942). In recent years there has been considerable interest in determining which field strain of *Gambusia* in California is most tolerant of organic pollution and could be most effectively employed in future introductions. Laboratory experiments were conducted in 1968 to establish comparative base line KD_{50} (knock down) oxygen values for a fresh water strain of *G. affinis* at 21.1, 26.7 and 32.2° C, which would enable future comparisons of field populations. *Poecilia reticulata* was included in the experiments based on observations of this species in highly organic waters by Johnson and Soong (1963) Sasa, et. al., (1965) and Nakagawa and Ikeda (1969).

METHODS.—A common method of determining the minimum oxygen tolerance of fish is the use of hermetically sealed glass containers in which the oxygen is removed by fish respiration over a measured time period. Burdick, et al. (1954, 1957) found the minimum oxygen concentrations determined in this manner corresponded closely to data obtained with other methods. Due to the simplicity and reported validity of this procedure, it was used in this study.

Gambusia were obtained from the Santa Ana River near Riverside, California, and *Poecilia* from a population maintained at the University of California, Riverside, Midgeville Field Station. The fish were held indoors at 21.1±1.7° C under a 12 hour photoperiod for a minimum of one month prior to use. All fish were isolated according to sex one week before testing, and were held at the test temperature for 24 hours prior to use. No food was offered the last 48 hours.

Test equipment consisted of pint mason jars held in a constant temperature (±0.6° C) water bath. With two exceptions, ten replicates of four fish each were used. Dissolved oxygen in each test was determined to insure air saturation values (8.7, 7.9 and 7.1±0.2 ppm at 21.1, 26.7 and 32.2° C respectively). Unsealed control jars were suspended at the surface of the water bath.

Table 1.—The oxygen concentration in parts per million at the KD_{50} of adult *Gambusia* and *Poecilia* at three test temperatures.[a]

Species & Sex	Mean Length (m)	Length Range	Weight (gm) Mean	Weight (gm) Range	KD_{50} Oxygen Concentration Minimum	Maximum	Mean	Std. Dev.	Std. Error
				21.1° C					
G. affinis ♂♂	24.0	19-28	.238	.130- .361	0.35	0.50	0.42	.059	.019
G. affinis ♀♀	31.6	25-40	.604	.302-1.250	0.20	0.30	0.23	.035	.011
P. reticulata ♂♂	18.6	15-23	.134	.056- .216	0.30	0.50	0.40	.062	.020
P. reticulata ♀♀	18.4	15-25	.116	.046- .309	0.20	0.30	0.24	.046	.015
				26.7° C					
G. affinis ♂♂	21.4	20-26	.160	.096- .280	0.70	0.70	0.52	.471	.167
G. affinis ♀♀	30.6	25-37	.532	.259- .750	0.40	0.45	0.42[b]	.025	.008
P. reticulata ♂♂	18.5	15-22	.130	.074- .223	0.40	0.60	0.44	.066	.021
P. reticulata ♀♀	21.9	17-32	.194	.070- .502	0.20	0.40	0.33[b]	.067	.021
				32.2° C					
G. affinis ♂♂	22.5	18-27	.205	.112- .291	0.60	0.90	0.73[c]	.290	.092
G. affinis ♀♀	29.0	24-37	.399	.196- .899	0.40	0.50	0.43	.048	.015
P. reticulata ♂♂	17.5	14-21	.101	.057- .152	0.40	0.60	0.52[c]	.063	.020
P. reticulata ♀♀	21.1	17-28	.149	.067- .318	0.30	0.50	0.42	.067	.022

[a]Combined control mortality was less than 0.5 percent at 21.1 and 26.7, and 2 percent at 32.1° C. The KD_{50} oxygen concentrations shown for the sexes of *Gambusia* and *Poecilia* were significant at the 0.01 level (*Gambusia* @ 26.7°C-0.05) at all three temperatures.
[b&c]Significant difference (0.01 level) between the same sex of each species at the indicated temperatures.

Table 2.–Elapsed time to the minimum oxygen tolerance level (KD_{50}) of adult *Gambusia* and *Poecilia* at three test temperatures. [a & b]

species & sex		elapsed time to KD_{50} in min. Min.	Max.	Mean	Std. Dev.	Std. Error
G. affinis	♂♂	350	515	427	182.0	57.6
G. affinis	♀♀	185	245	210	17.7	5.6
P. reticulata	♂♂	603	945	750	107.2	33.9
P. reticulata	♀♀	930	1,460	1,222	166.0	52.5
G. affinis	♂♂	320	388	354	24.5	8.7
G. affinis	♀♀	153	200	176	16.8	5.3
P. reticulata	♂♂	382	660	498	257.5	81.5
P. reticulata	♀♀	370	505	426	138.0	43.7
G. affinis	♂♂	115	200	161	28.6	9.0
G. affinis	♀♀	70	125	95	17.9	5.7
P. reticulata	♂♂	160	239	201	23.1	7.3
P. reticulata	♀♀	225	305	267	30.5	10.2

[a]Combined control mortality was less than 0.5 percent at 21.1 and 26.7, and 2 percent at 32.2° C.

[b]Significant differences (0.01 level) were shown between the males and females of each species at all three temperatures.

Once the jars were sealed, the fish were observed for activity and opercular movement (respiration), until the mean tolerance limit (KD_{50}) was reached. This limit is defined as the point in time at which half the fish lose equilibrium and remain on the container bottom for one minute or more (Burdick et al. 1954). After the elapsed time was recorded, the jar was removed from the water bath, and the dissolved oxygen immediately analyzed. Terminal carbon dioxide determinations were performed at random on three of each ten jars.

Dissolved oxygen was determined using the Standard Winkler (Alsterberg modification) method. Use of powdered reagents in individual plastic pillows (Hach Chemical Company) with starch indicator and end point titration with a one milliliter volumetric pipette gave 0.05 ppm accuracy. Length and weight data were recorded for all fish prior to preservation in 10% formalin.

RESULTS AND DISCUSSION.–The time to KD_{50}, length and weight of *Gambusia* and *Poecilia* used, and the minimum lethal oxygen concentrations are presented in Tables 1 and 2. An analysis of variance using a completely random design to compare KD_{50} durations found significant difference (0.01 level) between *G. affinis* males and females and between *P. reticulata* males and females at each test temperature. Significant differences (0.01 level) in the biomass of the sexes of each species appears to explain these elapsed time differences. The KD_{50} time at each temperature was less for *Gambusia* than for *Poecilia*. *Gambusia* are larger than guppies and presumably would have depleted the dissolved oxygen more rapidly.

Gambusia affinis and *P. reticulata* demonstrated increased metabolic rates, by more rapid consumption of oxygen (i.e., shortened elapsed time), at each increase in temperature. Fry and Hart (1948), Alabaster, et al., (1957) and Downing and Merkens (1957) reported similar data for other fish.

An analysis of variance employing a completely random design to compare the KD_{50} oxygen levels of female *G. affinis* and *P. reticulata* found a significant difference (0.01 level) at 26.7° C; similar analysis of male response indicated significance (0.01 level) at 32.2°C.

The ratio of the mean KD_{50} oxygen concentration of male *Poecilia* compared to male *Gambusia* at 21.1, 26.7 and 32.2° C was 1.05, 1.18 and 1.40, and for female *Poecilia* compared to female *Gambusia* 0.96, 1.27 and 1.00.

There was a significant difference in the KD_{50} oxygen concentrations of male and female *G. affinis* at all three temperatures (21.1-0.1 level; 26.7-0.05 level; 32.2-0.01 level). Comparison of the sexes of *P. reticulata* showed significant differences at the 0.01 level at each temperature.

The symptoms of fish asphyxiation were: gradual increase in respiratory rate, loss of equilibrium, irregular darting motions, and finally, laying on their side on the bottom of the container. Prior to death, the fish repeatedly darted to the top of the jar, each time in an apparent final effort. Some members of both species revived when transferred to aerated water. Upon removel of the jar lids to measure the KD_{50} oxygen levels, it was noted that most *Poecilia* able to reach the surface after having lost equilibrium, literally hung at the surface, and slowly recovered. *Gambusia* were seldom observed to recover under these conditions.

Fry and Black (1938) and Black et al. (1954) found in sealed respiration tests that bottles containing above average oxygen levels also contained higher levels of carbon dioxide. This concurs with the findings of Irving et al. (1941) who reported that carbon dioxide reduces the affinity of fish blood for oxygen. Comparisons of end point oxygen and carbon dioxide levels in the present study found a maximum of 40 ppm and a mean of 25 ppm carbon dioxide upon terminal analysis. These findings agree with Burdick's (Burdick et al. 1954) who found little variation and concluded carbon dioxide produced no significant effect.

The mean KD_{50} oxygen levels should not be interpreted that long-term survival or reproduction can occur at levels close to these minimums. The minimum oxygen levels demonstrated in this study, other conditions being favorable, merely reflect the ability of *G. affinis* and *P. reticulata* to survive similar levels for short periods under otherwise favorable field conditions.

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CHANGING PERSPECTIVES IN SYSTEMATICS OF MOSQUITOES IN CALIFORNIA

Richard M. Bohart and Robert K. Washino
University of California
Department of Entomology, 367 Briggs Hall, Davis, California 95616

Since publication of "The Mosquitoes of California" by Freeborn and Bohart (1951), our concept of mosquitoes in this state has altered greatly. Two calculations give some indication of the magnitude of the change. First, the total number of species and subspecies treated in 1951 was 41. Our latest figure is 48, an increase of about 25 percent (Table 1). Secondly there have been changes involving generic, specific or subspecific names in seven of the original 41 or about 17 percent (Table 1). These percentages, however, do not reveal the increasing complexity of culicidology brought about mainly by the vast accumulations of information during the past two decades. Much of the information resulted as a by-product of arbovirus vector studies by W. C. Reeves and his associates, and as part of control efforts by local mosquito abatement districts, the State Bureau of Vector Control and Solid Waste Management and the University of California. Aside from contributing to a severe problem of disease transmission and control, however, mosquitoes as a group are extremely interesting biologically and can easily be studied for their own sake. To better understand mosquitoes from this viewpoint, many basic biosystematic studies have been conducted since 1951 to improve the foundation of culicidology in California as well as elsewhere. A few of these are the revised nomencluature and homology of chaetotaxy in immature stages, notably by Belkin (1952 and 1953) and Barr and Myers (1962); improvements in identification of aedine eggs by Myers (1967), information on early stages of larvae (Bohart, 1954; Bohart and Washino 1957) and pupae (Pastermack 1960; Barr, 1963; Barr and Barr 1969). Certain taxonomic groups that caused difficulty previously became better understood from investigations conducted during this period. Most notably these included studies on the *Aedes dorsalis* complex (Barr, 1955; Carpenter and LaCasse 1955; Richards 1956; Bohart 1956), the *Aedes varipalpus* complex (Belkin and MacDonald, 1957; Zavortink 1969), the *Culex pipiens* complex (Barr 1957; Iltis 1966), and the nearctic *Anopheles maculipennis* complex (Kitzmiller, Frizzi and Baker 1967).

It is interesting to speculate on the sources of the California mosquito fauna. For instance, it seems likely that the so-called snow or mountain mosquitoes came into the state from the north along the Sierra. These species are *Aedes communis, hexodontus, fitchii, increpitus, cataphylla, hexodontus, pullatus, schizopinax, ventrovittis* and *cinereus. Culiseta impatiens* might also be included here. Certain species seem to have originated from Lower Sonoran areas in Baja California and southwestern United States. These are *Uranotaenia anhydor, Coquillettidia perturbans, Orthopodomyia signifera, Psorophora confinnis, Psorophora signipennis* and possibly *Culex pipiens quinquefasciatus*. Most of these species still have very restricted distribution in the state. It can be surmised that certain species invaded California from the north along the coast, taking advantage of relatively mild climate. These might be *Aedes dorsalis* and *squamiger, Anopheles occidentalis*, and *Culex pipiens*. Still another invasion may have come from the Great Basin including such species as *Aedes niphadopsis, campestris* and *flavescens*. Utah and Arizona may have contributed *Aedes sierrensis* and *deserticola*, entering across Upper Sonoran areas of San Bernardino County or thereabouts. *Aedes taeniorhynchus, Culex anips* and *Culex reevesi* may have merely moved north along the coast from Baja California. *Aedes sticticus* and *Aedes vexans* are two holarctic species that may have entered across mountain areas of low elevation to the north, and become established in the Central Valley. Even if these guesses are correct, this still leaves 18 species to be accounted for. A few of them, such as *Aedes bicristatus* and *Culex boharti* may have originated in California. Most of the rest are wide-ranging species and some of them may have been introduced by commerce. One example might be *Aedes nigromaculis*. A more recent find, *Aedes atropalpus*, may also be such a situation. One female in fresh condition was collected in a culvert near the American River by Richard Meyers, a student at Sacramento State College. Since the species is a wellknown larval inhabitant of rockholes, it can be theorized that it emerged from such situations along the American River. Its establishment in California needs verification.

When we consider the California fauna with respect to areas of origin, this may lead to a change in perspective and some thought about species of mosquitoes likely to be discovered in the future as long-time but obscure inhabitants, or as recently established introductions. Certainly there are indications that several "exotic" species have had ample opportunity to become established but have failed to do so. One example is the temporary infestation of *Aedes aegypti* in San Francisco, Angel Island and San Diego at the turn of the century (Kumm 1931). Although the infestation was attributed to ships from South and Central America, this mosquito has since been reported as being well established in southern Arizona (Bequaert 1946), and it will be interesting to speculate on additional introduced species that may or may not become established in California in the following decades.

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Table 1.–Changes in the California mosquito list since 1951.

Species added	Out-of-date old names	New names
Aedes atropalpus	*Anoph. pseudopunct. franciscanus*	*Anoph. franciscanus*
Aedes campestris	*Aedes varipalpus* of authors	*Aedes sierrensis*
Aedes deserticola	*Culex quinquefasciatus*	*C. pipiens quinquefasciatus*
Aedes melanimon	*Culex stigmatosoma*	*Culex peus*
Aedes niphadopsis	*Culiseta maccrackenae*	*Culiseta particeps*
Aedes schizopinax	*Mansonia perturbans*	*Coquillettidia perturbans*
Psorophora signipennis	*Orthopodomyia californica*	*Ortho. signifera*

AN ATTEMPT AT BRINE FLY CONTROL ON THE GREAT SALT LAKE

J. Larry Neilson

Magna Mosquito Abatement District

Magna, Utah 84044

Brine flies, the small blackish flies on the Great Salt Lake have continued to be a major problem over the past few years. Dr. Willis Worth, of the United States Department of Agriculture, has reported five species that are found on the Lake: *Ephydra hians*, *Ephydra cinerea*, *Ephydra packardi*, *Ephydra auripes* and *Ephydra pectinulata*.

These flies emerge from the Lake and swarm in great numbers on the surface of the water and along the shore, creating a nuisance to the tourists, bathers, resort owners and salt companies. Morton Salt Company and Leslie Salt

Company, both located on the south shore, have had pumps and filters plugged by brine flies.

The Great Salt Lake, 15 miles west of Salt Lake City, is 78 miles long, 40 miles wide and covers an area of 1675 square miles. Brine flies can be found on most of the shoreline. There are also seven main islands in the Lake and most of these contain the flies. The economy of this area has certainly been affected by these non-biting insects.

A great deal of study and field work has been conducted by highly qualified people, and several papers have been written concerning these flies. However, most of this work has been done on Antelope Island near the east end of the Great Salt Lake. My paper deals only with the south shore of the Lake, which is located in the Magna Mosquito Abatement District.

These flies have been active on the Great Salt Lake for many years; however, it wasn't until 1965 that they were brought to my attention. John Silvers, owner of Silvers Sands Beach, called my office that year and reported the flies were so bad people were running for their cars and leaving the beach.

After an inspection of the area, it was decided that we would try to control the flies by spraying with ground equipment. Very little success was realized even though we tried several different materials, applying them with a Dyna-fogger and a Buffalo turbine sprayer. The Magna District had no funds to continue this program, so Mr. Silvers started a spraying program of his own, applying fuel oil to the beach areas and fog around the buildings.

This daily spraying reduced the flies to a tolerable level; however, it did create other problems. The fuel oil wasn't the most desirable material to have on the beach, and the millions of dead flies and pupae skins which washed ashore created a very offensive odor. This mess had to be cleaned up daily by employees of the resort.

Mr. Silvers has continued this type of control for the past several years at a cost to him of over $70 a day during the summer months.

Early last year (1971), several investors expressed a desire to build a multi-million dollar resort complex on the south shore. However, they were very concerned about the great number of brine flies which are active in the area and the nuisance they would cause to the people.

The Salt Lake Area Chamber of Commerce became concerned about the problem and contacted my office for assistance. They wanted to start a test project in the area. However, it was late July before the Chamber could make all arrangements for a testing program. I agreed to act as an advisor and help in setting up a test plot on the south shore.

Test cups were set up 50 feet apart at the water's edge and as far back as 25 feet from the water's edge. Each cup contained 20-25 adult flies of four different species. One cup containing 20-25 flies was kept isolated from the test area for comparison later in the day.

It was decided that malathion five would be the main insecticide because of the safety factor and the success of this material against the flies on Antelope Island. Malathion would be applied at the standard recommended rates of the manufacturer.

Equipment used for this test program was a Buffalo turbine sprayer, a London fog generator and a Bell 250 horsepower helicopter equipped for spraying. Each piece of equipment was used in separate test areas and on different days. All spraying was done in the early morning hours with wind condition of two to five miles per hour.

The turbine sprayer seems to do a better job than the fogger, killing 100% of the flies in the test cups in less than an hour and reducing the flies on the beach by approximately 80%. However, neither ground machine reached far enough out into the water. Many of the flies were resting on the water as far as 100 yards or more out on the Lake. Within 24 hours, fly populations were back in large numbers. This equipment also bogged down in the sand.

The helicopter was then tested, treating an area approximately 500 yards long and 250 yards wide, 50 feet back from the water's edge and 200 yards out on the water. Test cup kills were 100% forty five minutes after each flight and reduced the number of flies on the beach by at least 90%. This test plot was treated by the helicopter on three consecutive days.

For several days no spraying was done and the test area inspected daily. The brine fly count remained very low for approximately 56 hours. On the fourth day of inspection the fly population began increasing, and by the sixth day the flies were very numerous in the test area.

Following this period strong winds hit the area, and the tests were halted for the season.

This project really didn't last long enough to reach any final conclusions; however, I feel that the helicopter is very suitable for this type of control, and malathion seemed to do the job when applied at .04 to .05 pound per acre by the helicopter.

How often the area should be treated and how much of the area should be treated is something that has to be determined with future testing started earlier in the season.

These flies could have some ecological value to the Lake, and spraying of the entire south end of the Lake would be very expensive and unwise.

I realize that this fly can never be completely eliminated, but if the resort areas could be sprayed when this pest is active, they possibly could be kept at a tolerable level.

Future plans by the Chamber of Commerce for 1972 call for a $10,000 budget to continue the testing program on the south shore of the Lake. This program will be started by June 1, if funds are made available.

This program will be under the supervision of the Salt Lake Area Chamber of Commerce and the Utah Parks and Recreation.

INUNDATION WITH PARASITIC INSECTS TO CONTROL FILTH BREEDING FLIES IN CALIFORNIA[1]

E. F. Legner[2] and E. J. Dietrick[3]

The instability of most fly breeding sites on dairies, poultry, and horse ranches often requires special attention and immediate control efforts at unpredictable intervals. Well managed ranches undergo few fly upsets compared to operations where management is difficult or not understood. The economic position of a particular ranch also restricts the efficiency of a management effort.

When upsets occur, immediate measures are required to reduce fly abundance. Formerly, poison baits and larvicides alleviated such problems but, as resistance developed, other remedies were sought. Mass releases of parasitoids seemed one obvious way to directly reduce fly breeding. This report reviews progress with mass releases in California and its feasibility in integrated fly control.

In the early 1960's, researchers at the University of California, Riverside, began to seek alternatives to pesticides. Investigations revealed parasitic insects that attacked larvae and pupae of most noxious flies in filth habitats (Legner, 1965, 1966, 1971; Legner and McCoy 1966; Legner and Olton 1968a; Legner et al. 1966, 1967). Although scores of predatory and scavenger species also existed in the breeding habitat (Legner and Olton 1968b; Peck and Anderson 1969), the parasitic forms were initially favored because of their ease of mass production and their abilities to seek out later developmental stages of flies which resulted in a direct reduction of fly emergence.

The first series of parasitic inundation experiments was conducted in 1964 (Legner and Brydon 1966; Legner et al. 1966), producing a significant but low reduction in *Fannia* emergence in the release area (about 24%) (Legner et al. 1966). The effects endured through the winter and spring *Fannia* season. These studies led to a worldwide search for additional parasitic species that might be more adapted to California's climate and for forms that could demonstrate greater activity during the comparatively cooler winter and spring *Fannia* seasons. Although additional parasitic species were found, only *Tachinaephagus zealandicus* Ashmead showed a definite preference to parasitize flies during the cooler, more humid seasons (November-April). This species, attacking larvae of filth flies, was tested successfully in mass release trials during late winter and early spring of 1970 (Olton 1971). Parasitization of larvae was effected in poultry manure test sites where few natural enemies existed prior to the inundative releases, and fly emergence was significantly lowered.

The final stage in evaluation of the inundative technique which is presently under way, stresses three climatically adapted parasitoids. Twelve poultry ranches in the San Bernardino-Upland area were selected in 1970 for a comprehensive test of this method, with six chosen at random for checks and six for release sites. Thousands of parasitic wasps were released on the six ranches beginning in March of 1970. The species released were native strains of *Muscidifurax raptor* Girault and Sanders, and *Spalangia endius* Walker, and the imported Australasian *T. zealandicus*. A sample of pupae of the principal fly species present in June, 1970, revealed a 6.5 times lower density and almost double percent parasitization on the release ranches (Table 1).

Continuing mass releases in 1971 stressed *S. endius* alone during the warm seasons and both this species and *T. zealandicus* during the fall and winter months. The objective was to reduce late winter and spring emergence of *Fannia canicularis* (L.) and *F. femoralis* (Stein) by parasitic attack. A complete cost account will accompany the outcome of the current tests to assess the practicality of using this method in direct control.

Should the inundative method be practical in the reduction of fly upsets, improved mass release techniques through the liberation of exotic strains of the same species from geographically isolated areas of similar climate are available. Basic studies with the hybrid progeny of crosses between domestic and exotic strains have shown the hybrids to be superior in activity and longevity to either of the parents, the effect sometimes extending into additional filial generations (Legner 1972).

Further emphasis on biological control of filth flies will stress studies in other habitats (dairies, feedlots, etc.) and will involve the introduction of additional parasitic, predatory and scavenger species from Africa and portions of Asia where low density fly populations occur in apparently suitable breeding habitats (Legner and Greathead, 1969; Legner and Olton 1970; Legner, unpublished data).

Table 1.–Fly density and percent parasitization on integrated versus check poultry ranches in the San Bernardino-Upland area, California, on June 17, 1970.

	Integrated Control[b]	Check
Avg. density of emerged flies per liter of poultry manure[a]	2.1	13.8
Percent parasitization of all fly species	22.5	12.9

[a]Fly species include *Musca domestica* L., *Fannia canicularis* (L.), *Muscina stabulans* (Fallen), *Ophyra leucostoma* (Wiedemann), *Stomoxys calcitrans* (L.), *Phaenicia* spp., and Syrphidae.

[b]Inundation with large numbers of parasitoids and continuous maintenance of six inches or more of manure habitat.

[1]Research partially supported by Grant Nos. GM-12699 and GM-12496 of the National Institutes of Health, U. S. Public Health Service.

[2]University of California, Department of Entomology, 134 Entomology, Riverside, California 92502.

[3]Rincon-Vitova Insectaries, Inc., 19522 El Rivino Road, Riverside, California 92509.

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FLIGHT AND FORAGING PATTERNS OF GROUND–NESTING YELLOWJACKETS AFFECTING TOXIC BAITING CONTROL PROGRAMS[1]

Calvin J. Rogers

San Mateo County Mosquito Abatement District

1350 North Carolan, Burlingame, California 94010

Specific information on the flight and foraging habits of ground-nesting yellowjackets has been meager due to the uncooperative nature of these wasps. Some of the difficulties encountered in yellowjacket marking and recovery have been overcome allowing investigation of these factors, essential to both the development and evaluation of control programs, to proceed. These studies have been undertaken to provide some insight into these important areas.

METHODS AND MATERIALS.—These studies were conducted near the town of Woodside, San Mateo County, California. The yellowjacket colonies used were situated in an uncultivated, fairly open, grassy, rolling hill area with scattered oak and madrone trees. The study area, ranging from 440 feet to 730 feet in width by slightly over one-half mile long, was bounded on the northeast by a paved road and on the southwest by a creek and a heavily wooded hillside; the southeast and northwest ends were continuations of similar terrain. Portions of the southeastern end of the area were cultivated (barley and a small orchard), and other portions were devoted to natural pasturage for horses. The study area is typical of yellowjacket producing areas in San Mateo County.

[1]Special thanks are extended to C. Donald Grant for his support of these studies and review of the manuscript, and to Steven Burkey and Kelly L. Crawford for their assistance in the field.

Fortuitous location of two nests, one *Vespula pensylvanica* (Saussure) and the other *Vespula vulgaris* (L.) were only 5 ft. 3 in. apart, centrally located in a relatively clear region of the test area, and afforded excellent opportunity for comparative study. Unfortunately, before activity counts could be made, the *V. vulgaris* nest was destroyed by a maurading animal. However, the activity of the *V. vulgaris* nest appeared to be on the order of three to five times as great as that of the *V. pensylvanica* nest. Upon excavation the *V. vulgaris* nest was found to occupy a cavity of approximately 255 cubic inches while the *V. pensylvanica* cavity was approximately 154 cubic inches in volume, further indicating the larger size of the *V. vulgaris* colony.

Yellowjackets were marked at the nest site with a daylight fluorscent pigment dust using the method described by Rogers (1972).

Standard yellowjacket traps (Rogers and Lauret 1968) with cooked horsemeat bait (Grant et al. 1968) were used to recover the marked wasps. Fresh bait was provided on each day of the study. The traps were placed at various distances from the nests to obtain information on both short and long range flight and foraging habits. Traps for short range flights were arranged in three concentric circular patterns with the traps equally spaced on specific compass bearings wherever possible. The inner circle consisted of three traps on a 20 foot radius at 0°, 120°, and 240°. The second circle consisted of eight traps on a 100 foot radius at 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°. The third circle, incomplete due to limitations imposed by vegetation and topography, consisted of five traps at 70°, 90°, 135°, 270°, and 315°. The placement of long range traps was severely restricted by topography and available space. Therefore, only six traps were used, three at ¼ mile (1320 feet) and three at ½ mile (2640 feet) from the marked nests on bearings of approximately 290° and 305° respectively. In addition to these, five traps normally used for population surveillance were checked for marked yellowjackets. These were located from 400 to 845 feet from the nests on bearings ranging from 260° to 275°.

The studies were conducted between August 30 and September 23, 1971.

RESULTS AND DISCUSSION.—Flight Range: Marked wasps were recovered at distances ranging from 20 to 1320 feet from the marked nests; none was recovered by traps at the 2640 distance. The rate of recapture declined steadily as distance increased (Fig. 1).

Contrary to previous suspicions that yellowjackets are not readily attracted to food sources near the nest, traps placed only 20 feet from the nests produced the highest recovery rate for both colonies. The absence of marked individuals at the 2640 foot distance was probably due to an insufficient trapping time period and too few traps rather than to the flight range potential of the wasps. Obviously strong fliers, they are probably capable of longer flights.

When considering flight range in relation to control program effectiveness and efficiency we are looking for an

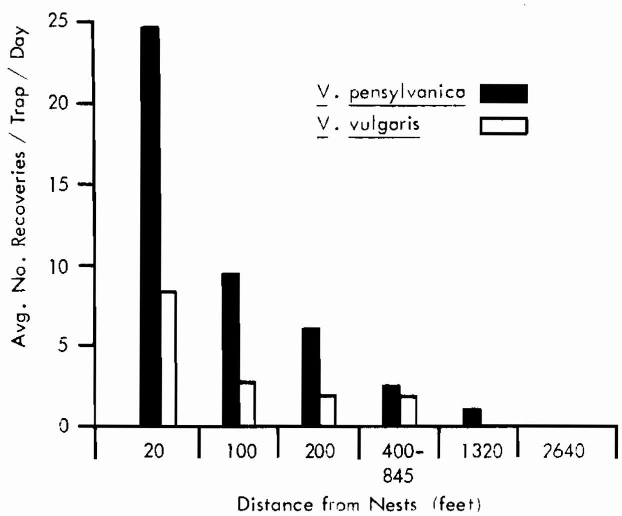

Fig. 1.—Recoveries of marked yellowjackets at various distances from the nests.

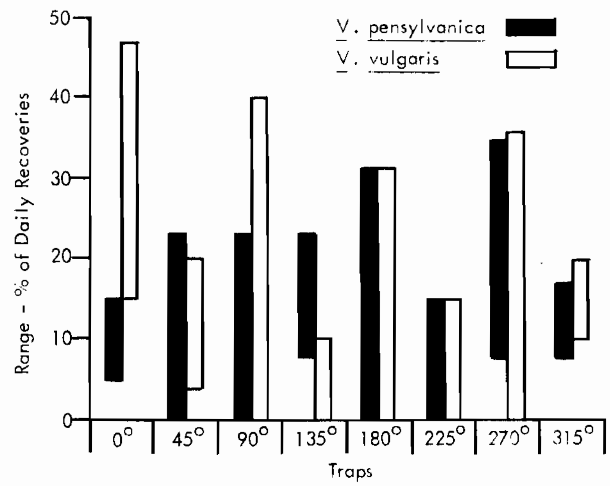

Fig. 2.—Variation in foraging patterns as shown by the range in individual trap collections over a five day period, expressed as percent of daily recoveries.

Table 1.—Variation in foraging patterns as shown by recovery of marked yellowjackets in individual traps located 100 feet from the nests over a five day period.

Trap	Percent of Total Recoveries / Trap / Day									
	8/30		8/31		9/1		9/2		9/3	
	pen.[a]	vul.[b]	pen.	vul.	pen.	vul.	pen.	vul.	pen.	vul.
0°	15	20	12	43	7	47	8	23	5	15
45°	23	20	11	4	1	7	0	8	9	5
90°	0	40	7	4	20	0	23	15	8	3
135°	15	0	12	0	13	0	8	0	23	10
180°	0	0	9	30	17	20	31	31	6	13
225°	15	0	5	0	0	0	15	15	*	*
270°	15	0	26	4	27	7	8	0	35	36
315°	15	20	17	13	15	20	8	8	13	18

[a] *V. pensylvanica*
[b] *V. vulgaris*
*Trap damaged.

"effective range", i.e., one which permits installation of the minimum number of toxic bait dispensers that will still attract sufficient numbers of wasps from all local colonies to provide rapid and effective control.

These data indicate that dispensers placed about 200 feet apart will provide adequate coverage for most areas. Such placement would provide at least one bait station within 100 feet of any nest in the area and three other stations within 200 feet. The results also indicate that control effectiveness would be increased by the dispersal of dispensers throughout the control area, thereby, locating toxic bait material nearer nests within the area. However, the second factor of time and area variability in foraging patterns needs further study. Restricting the dispensers to any particular region, such as the periphery, would tend to place the bait at greater, and less favorable, distances from centrally located nests. Peripheral baiting, however, should not be ignored as dispensers so located would be most effective in attracting wasps from nests outside of the control area which may be contributing to the foraging population within the area.

Dispensers placed at 200 foot intervals produce a density of approximately one per acre, which has been successfully used as a standard in District control programs for the past several years. Control results also have shown that in heavily forested areas increasing the bait density to one per ¾ acre produces a more desirable level of control.

Foraging Pattern: A highly variable foraging pattern was demonstrated for both species by recoveries in traps at all distances from the marked nests. This variability was exemplified by a five day study (August 30 to September 3) using the 100 foot trap circle. During this period individual trap collections ranged from 0 to 47% of the daily totals, and no pattern uniformity nor directional preference was evident (Fig. 2 and Table 1). There did not appear to be any foraging pattern carry-over from day to day; patterns apparently were established anew each day.

Maximum exposure of the toxic bait to yellowjacket workers is an important factor to the success of the control program. Dispersal of the dispensers throughout the control area (as discussed under "Flight Range") provides such exposure to wasps foraging in this variable manner and, therefore, is again recommended.

Species Differences: It has been observed, from the results of previous baiting programs, that *V. vulgaris* is more difficult to control than is *V. pensylvanica*. Almost invariably the decrease in population levels, resulting from control efforts, are greater for *V. pensylvanica* than for *V. vulgaris*. It was thought that this was due, at least in part, to the preference of *V. vulgaris* for areas of heavy vegetation, making it more difficult for the wasps to locate the bait dispensers.

It now appears that another, and possibly more important, factor is producing this effect. During this study, considerably larger numbers of *V. pensylvanica* than *V. vulgaris* were recovered in all cases regardless of the distance of the traps from the nest (Fig. 1). A total of 1206 marked wasps were recovered, of these 878 were *V. pensylvanica* but only 328 were *V. vulgaris*. This is in spite of the larger size and greater activity of the *V. vulgaris* colony.

This leads to the conclusion that *V. vulgaris* workers are more attracted by other protein sources. Perhaps they prefer predation (known to occur in both species) to scavenging as a method of acquiring larval food materials.

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FIELD TESTING OF "YELLOW JACKET STOPPERS"® AND POPULATION DEPLETION TRAPPING FOR THE CONTROL OF GROUND–NESTING YELLOWJACKETS[1]

Calvin J. Rogers

San Mateo County Mosquito Abatement District

1350 North Carolan, Burlingame, California 94010

The San Mateo County Mosquito Abatement District has been engaged in the study and development of control techniques for ground-nesting yellowjackets, *Vespula vulgaris* (L.) and *Vespula pensylvanica* (Saussure), for the past several years (Grant et al. 1968). The 1971 program included field testing of the recently introduced "Yellow Jacket Stopper"® (Allied Chemical Corporation) and control by the depletion of the foraging yellowjacket population through trapping. The tests were conducted in picnic and camping areas of Huddart Park, a wilderness park, located near the town of Woodside, San Mateo County, California.

[1]Special thanks are extended to C. Donald Grant for his support of these studies, and to Steven Burkey and Kelly L. Crawford for their assistance in the field.

Yellow Jacket Stopper Test

METHODS AND MATERIALS.–Yellow Jacket Stoppers are commercially prepared units consisting of a bait dispenser, canned toxic bait, and a chemical attractant. The units were placed near the borders of the test area (Madrone Area) 100 to 150 feet apart as per label instructions. Thirteen units were used in an area of approximately thirteen acres. They were installed during the third week of the season and were removed during the tenth week, a period of eight weeks (July 7 to August 23, 1971).

A similar area (Lower Area) was used for comparison wherein standard District control methods (Grant et al. 1968) were employed. Toxic baiting with cooked horse-meat and 1% Chlordane was applied for two periods of three days each during the fifth and eighth weeks of the season.

Both sites were picnic grounds which included clear areas, forested areas, and some brush. The yellowjacket populations in both sites were predominately *V. vulgaris* with only few *V. pensylvanica* present.

Evaluation of control effectiveness was determined by trapping, using standard yellowjacket traps (Rogers and Lauret 1968). Because of the low numbers of *V. pensylvanica*, only *V. vulgaris* population measurements were used for evaluative purposes, while populations refer to foraging workers trapped.

RESULTS AND DISCUSSION.–The criteria used by the District for determining control effectiveness is the "annoyance threshold" of 50 yellowjackets/trap/week. Desirable control is achieved when populations within an area are maintained below this level.

The population in the Lower Area approached the "annoyance threshold" during the fifth week and standard District control (Toxic Baiting) procedures were initiated. The population again increased during the seventh week (a phenomenon frequently observed) requiring an additional baiting in the eight week (Fig. 1). No further control measures were required in this area.

The population in the Madrone Area, where the Yellow Jacket Stoppers were used, remained below the "annoyance threshold" for seven weeks. A sudden increase during the eighth week necessitated initiation of standard District Toxic Baiting (Fig. 1).

There was some indication that the population in this area was being supressed for the first seven weeks, particularly during the sixth and seventh weeks. During this period yellowjackets were observed visiting the commercial dispensers, but the initial liquid consistency of the bait, and the subsequent development of a hard surface layer, apparently restricted the amount of bait material that could be removed by the wasps.

There is also the possibility that current processing and canning operations may adversely affect the bait attractiveness.

Population Depletion Trapping

Control of yellowjackets by population depletion trapping, i.e., trapping wasps in sufficient numbers to maintain

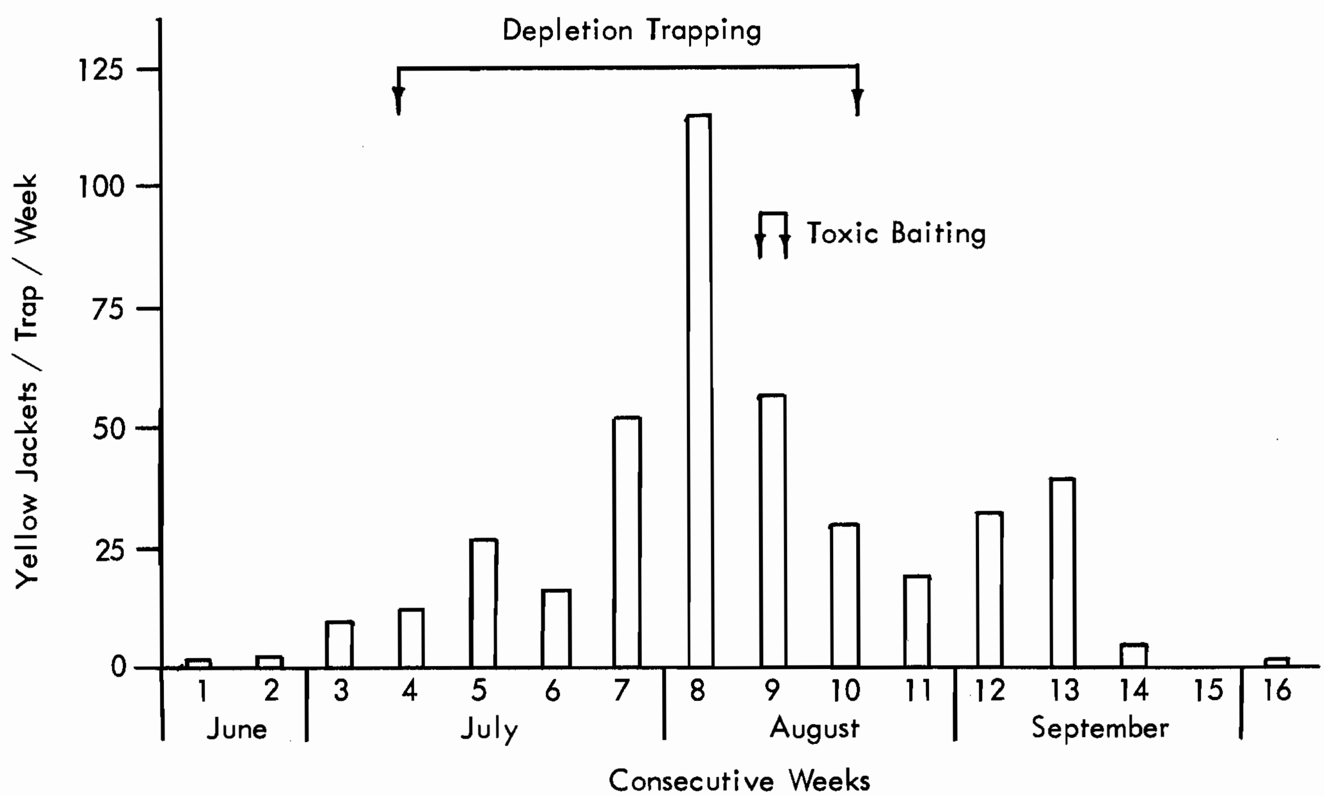

Fig. 1.–Comparison of control results using "Yellow Jacket Stoppers"® in the Madrone Area, and standard District Toxic Baiting methods in the Lower Area of Huddart Park.

the population level below the "annoyance threshold", was tested in one park area as an alternative to chemical control.

METHODS AND MATERIALS.—This test was conducted in a family camping area of approximately 20 acres. The area was rather heavily forested with coast redwood, madrone, and oak. The yellowjacket population consisted almost completely of *V. vulgaris*, and only two *V. pensylvanica* were trapped during the 1971 season.

Twenty standard yellowjacket traps (Rogers and Lauret 1968) were distributed throughout the camp grounds, and were baited weekly. In addition to these, three traps as used annually for population evaluation were installed. The depletion traps were maintained for seven weeks (July 14 to August 24, 1971), the fourth through the tenth weeks of the season. The evaluative traps were in operation throughout the season.

RESULTS AND DISCUSSION.—Although, a total of 6,069 yellowjackets were trapped during this period, the population was still able to rise well above the "annoyance threshold" during the seventh, eighth, and ninth weeks (Fig. 2). It was necessary to initiate toxic baiting procedures in the ninth week to lower the population to acceptable levels.

The inability of this method to adequately control *V. vulgaris* might have been foretold if the studies with marked yellowjackets had been complete (Rogers 1972). These studies indicated that *V. vulgaris* is not as readily attracted to the bait material as previously supposed. However, the cooked horsemeat bait appeared to be highly attractive to *V. pensylvanica* and control of this species may be possible using depletion trapping.

Another factor adverse to depletion trapping was the competition between the bait material and the abundent food supply provided by the campers while preparing and eating their own food, and the resulting garbage deposited in open refuse cans.

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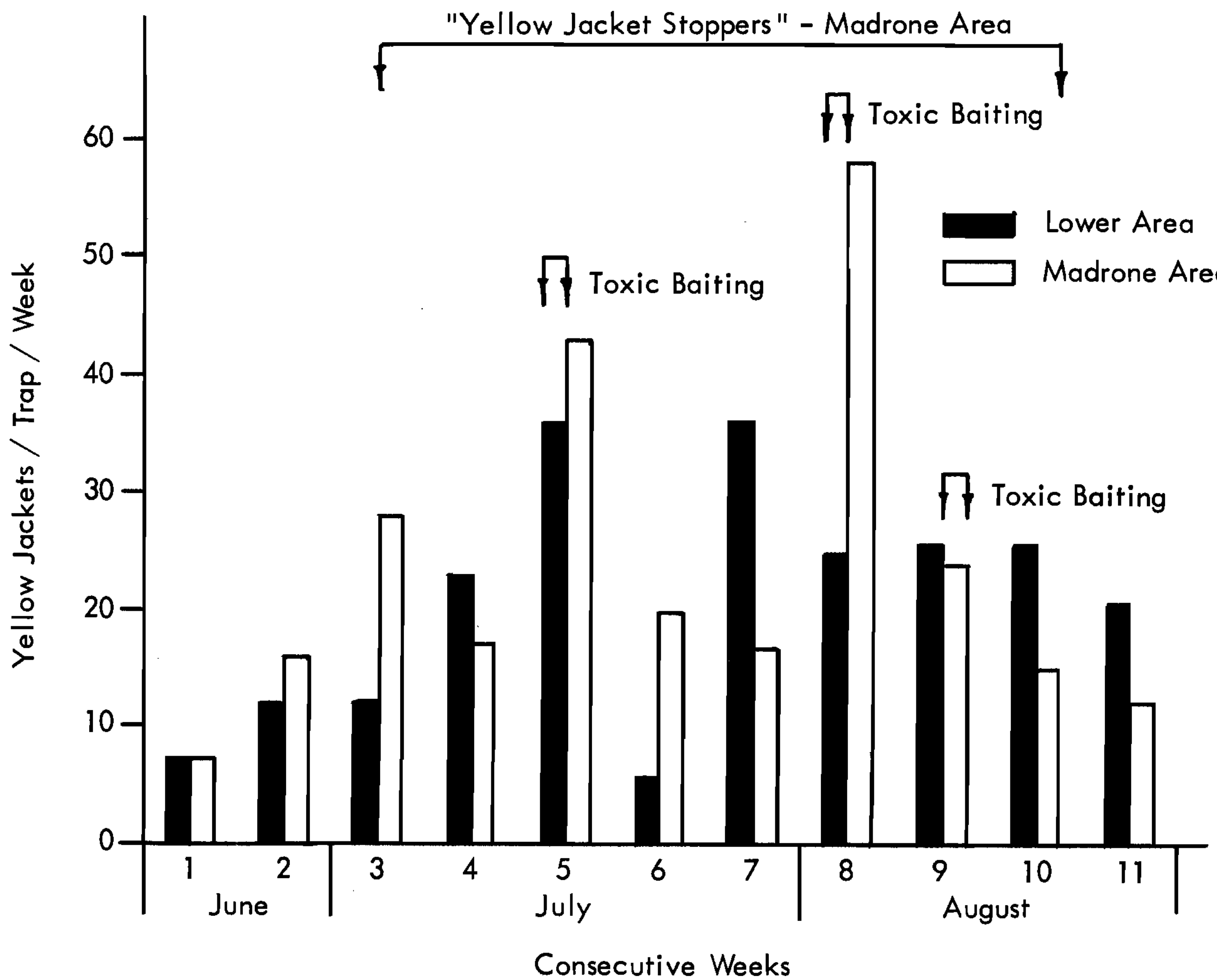

Fig. 2.—Results of population depletion trapping on a population of *V. vulgaris*.

COMMITTEE OF THE FUTURE REPORT

James W. Bristow

Southeast Mosquito Abatement District

9510 South Garfield Avenue, South Gate, California 90280

"Once you acknowledge the reality of change, once you, recognize your own part in determining the direction of that change, you need no longer despair – you will find the world vivid with hope," Dr. S. I. Hayakawa, President, San Francisco State College.

This report will be divided into several sections in an effort to treat the many aspects of change which may be expected in the future. According to our CMCA 1971 Year Book, mosquito control is active in an area covering 40,000 square miles, or about 25 percent of the State and this includes some 13,700,000 people, or about 70 percent of the population.

All districts and health departments, to some extent, use public health protection chemicals and maintain a surveillance to measure mosquito and other vector populations of their respective areas. All use source reduction as a major tool of suppression.

Before proceeding any further with this matter, I would like to define two words which have been tossed around by many and sundry "experts". They have taken on an emotional nature and have been misused in too many cases for me to even try to document them here.

Webster's Third New International Dictionary defines "Ecology": "A branch of science concerned with the interrelationship of organisms and their environment, especially as manifested by natural cycles and rhythms, community development and structure, interreaction between different kinds of organisms, geographic distributions and population alterations."

"Civilization": "The whole of the advance of human culture and aspirations beyond the purely animal level."

"Civilization is the descriptive inventory of all of the modifications brought about in the normal life of man in society." (Pierre Lecomte du Noüy)

The first item I would bring to your attention is the governmental structure of this State and the nation in general. The history of our California governmental structure reflects the experience of the pioneers who came to California from the eastern states where "bossism", graft and outright dishonesty in local, county and state government were accepted norms. These pioneers were successful to a great degree in setting up laws to prevent this type of abuse in California. The "Brown Act", to prevent secret meetings, and the conflict-of-interest laws, to prevent members of governing bodies from profiting from the nonpartisan election for city and county government, have prevented the growth of huge party machines below the state level. In spite of what many may say, California is one of the best governed states in the Union.

However, we are addressing ourselves to the future. The San Francisco Bay Area now has seven separate and distinct entities of regional government, none of which is, by law, responsible for or to the other. They are, to all intents and purposes, regional districts with separate powers and responsibilities to perform specified acts.

The Legislature has not formed one actual regional government in California with the power to act in all matters concerning the encompassed counties and cities.

Regional problems are being handled in the same general manner as the Mattoon Act, enacted early in this century, lays out.

The regional concept of government has been used throughout the State by the formation of special districts such as the Metropolitan Water District which extends from Ventura County to San Diego County with its services; the Southeast Mosquito Abatement District with 26 cities and the County of Los Angeles. There are others too numerous to mention.

I can see no reason for the California Legislature to change the method of control of regional problems. The pressure for regional government comes not so much from the people involved as from the Federal government. The most recent trend toward direct grants to cities portends a broader concept of help and added strength to local control. The huge megocentropolis envisioned by the cloistered advocates of centralized control are a long way into the distant future. I sincerely doubt that any one of us will live to see such. (See Footnote [1] (page 137) for Divergent Opinion)

The purpose of mosquito control is to protect the public it serves from disease-producing and pest insects which endanger human well being. The objective, then, is to protect rather than to destroy. Therefore, when making changes, all factors existing in an environment must be considered prior to any action taken. Changes in the environment considered here are physical and biological. Biological and/or physical changes which are made in any environment cannot be considered separately because ecology concerns all living things. When an environment is physically altered (leveling, filling, etc.) the natural habitat is drastically changed.

Mosquito control insecticides of the immediate future will place very significant reliance on petroleum hydrocarbons such as Flit® MLO. Subsequent control materials and approaches will utilize insect sterilants, bacteria, protozoa, viruses and genetic manipulation. Very specific and single-purpose items aimed at controlling only one organism (mosquitoes) will be developed and utilized. Adequate levels of mosquito suppression cannot be attained by complete reliance upon mosquito source reduction. Supportive measures will be essential and will include the use of toxicants of various types. Source reduction, however, will increase in importance as the cost of the public health chemicals increases. The cost increase is now being felt in many areas and may become so acute in the near future that control beyond source reduction could be completely abandoned. Limitations on the use of permissible public health chemicals have already curtailed the use of toxicants by some districts in our Central Valley due to the complete immunity built up by the mosquitoes. Testing of new chemicals has almost been abandoned by the manufacturers. The cost of testing and obtaining approval for the use of new chemicals has become so prohibitive that manufacturers cannot afford the investment while other more lucrative avenues of cost return lay open to them.

Since mosquitoes have become tolerant to organophosphorus insecticides, "prescription" application of these chemicals is now the general approach to mosquito control. By "prescription" applications I mean the use of a specific chemical to control a specific mosquito species in a particular source.

In the future we will see an expansion of "prescription control", which will feature environmental manipulation and naturalistic approaches as the standard practices, with chemical control descending to a supportive role. The primary objective in future mosquito control programs will be source prevention.

Mosquito abatement districts for some time now have used local funds for research connected with the immediate problems of the district area. Several of the larger districts have provided funds to the University of California to do research on specific areas and problems. Funds for broad research by the University of California have been severely restricted by the administration of the University itself and further by the attitude of the Legislature and the Governor toward advancing funds for general use. Future research in the broad area of public health chemicals will have to be done with Federal or State funds or not be done at all.

The outright banning of the use of public health chemicals has not as yet run its course. The so-called "environmentalist" concern over ecology has forgotten the meaning of the word (or has never bothered to learn it.) Civilization has suffered through the centuries with plagues, pestilence, wars and disasters, and, although halted for a time, has picked up the pieces and gone on to greater and better things. I cannot believe, at this time, that the lawmakers of this land will be so blind as to wait until some disastrous epidemic of disease occurs to see the true meaning of ecology as it relates to civilization and the environment of man.

The lead time needed for development, testing and approval for public health chemicals has been increasing for some time. DDT and its derivatives were manufactured and put into general use during WW II with a lead time of about two years. Today, lead time is at a minimum of five years with no products on the upcoming market that meet the needs of the public health sector. Any product that will meet those needs and satisfy the environmentalist restrictions will undoubtedly be prohibitively expensive to manufacture, distribute and apply.

When making physical changes in the environment, consideration must be made as to how these changes will affect; a) the natural animal and plant balance existing in the area; b) the physical aspects of the area, i.e.: erosion (water and wind), percolation, salt balance; c) agriculture, i.e.: economic, production, pest control, water usage, etc.; d) the commercial and industrial developments; the homeowner.

Considerable evaluation, then, of all environmental factors involved will be thoroughly made in the future prior to recommending any alterations to be effected in a habitat.

Naturalistic changes in a habitat can generally be divided into three very broad categories, namely; a) by the addition to the environment of naturalistic control agents; b) by eliminating (excluding) organisms which inhibit the development of natural control agents; c) by manipulation of existing and introduced natural control agents.

Naturalistic control agents present, in permanent and semi-permanent (rice) waters, the most promising, yet challenging and perplexing, approaches to mosquito control for the future. A delicate balance of predator-prey; disease-host; and physiologic-genetic makeup must be maintained or altered to keep mosquitoes below the disease and/or pest thresholds.

To effect "prescription control" by use of environmental and/or naturalistic methods, the precise approach for the particular problem (or mosquito source) must be made. To make this decision, a complete analysis of the problem must first be made. This analysis would include records on all existing physical and biological factors and also an evaluation of the potential outcome when these physical and biological factors are manipulated or altered.

Accumulated records acquired by ground and air surveillance will eventually change the mosquito control approach to one of "prescription mosquito prevention and control". Foreseen is the use of "indicators" which show up in agricultural areas as forerunners of mosquito problems. Correction may be effected, thus, before the mosquito problem becomes actual. Aerial surveillance by photography is seen as a key to future mosquito source prevention and control.

Good record keeping is a key to the success in precise "prescription source prevention and control". Standardized record keeping and pooling of data into a centralized retrieval system among California districts will aid considerably in putting into immediate practice the practical knowledge acquired anywhere in the State.

Manpower needs of the future is an area of more than passing concern. Two factors much discussed in the past must be faced.

The first is the upgrading of the personnel who actually do the work in the field – spraying, dusting, source reduction, water management, other vector control and the upkeep of equipment and records used to show what is done and what it costs to reach acceptable levels of control. Certification of the manpower by State authority offers both a solution and a dilemma. To educate and certify personnel means that thereafter their employment must be on year-round basis. Seasonal employment, except for apprentice personnel, as is now practiced, will be at a minimum. Highly trained certified personnel will demand higher wages and working conditions as well as improved fringe benefits now avoided or held to a minimum by the seasonal nature of mosquito control. Hopefully, however, the program of the future will be more qualitative and should require fewer overall staff possessing greater qualifications.

The second factor is the coordination of methods, means and procedures used by the various districts. The logical coordinator should be the State Health Department, Bureau of Vector Control and Solid Waste Management.

The dedicated work of the staff of this Bureau in giving assistance, guidance and information to the mosquito control districts is a story that need not be recounted here because you in this audience have been the recipients of that help. We in the CMCA, since 1965, have asked, begged, petitioned and demanded that the staff of the Bureau be expanded to meet the greater needs of the districts. Both the executive and the legislative arms of the State have turned a deaf ear to our pleas. Had the requests for source-reduction engineers, agricultural specialists in irrigation methods and other highly-qualified people been heeded long ago, our position on many of our projects would be highly improved. The taxpayers in the districts would have, no doubt, saved many times the cost of such specialists.

Today change is swift. This is the direct result of a deluge of new knowledge in practically all fields of endeavor, bombarding us from all directions. However remote much of this new knowledge may seem from our interests, we may safely assume that we, too, will be caught up in new technology that will extend or outmode our old methods.

Traditionally, we put chemists in one compartment, engineers in another, biologists in another, and so on. The well-defined spheres of knowledge and competence in the past were possible because one individual could assimilate most of the knowledge available in a particular discipline. The concept of compartmentalized professionals worked well to solve routine problems which occurred at a moderate rate.

The problems we in mosquito control face now and in the future are neither routine nor infrequent. Mosquito prevention requires the knowledge to be found in several disciplines — chemistry, biology, engineering, zoology, and so forth, including expertise in molding public attitudes. The rising tide of new knowledge forces people to the various disciplines into ever narrower specialization.

The people to whom we will be looking in the future will necessarily be highly specialized in their respective fields, capable of sorting out the bits of information from the vast store of available knowledge that is applicable to the highly specialized job of preventing or controlling mosquitoes. The specialists will work as teams, combining disciplines, to solve problems in mosquito control.

In addition to horizontal integration of disciplines, the relationships of managers, operational personnel and ground level technicians, with the experts and specialists, will evolve into direct consultation with each other. This will allow all levels to participate in decision making. Direct consultation at all levels will accelerate decision-making as well as implementation of new technologies.

In conclusion, let me state that ever since the beginning of time, man has evidenced concern about tomorrow. What happened yesterday is history. Today is barely tolerated because tomorrow is the suspenseful future. If we, here as members of the Committee of the Future for 1971, have enlightened you in any way, then we have fulfilled our function.

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[1] SPECIAL DISTRICTS AS ENTITIES OF GOVERNMENT

Howard R. Greenfield
Northern Salinas Valley Mosquito Abatement District
Post Office Box 5037, Salinas, California 93901

--With few exceptions, special districts governed by boards of trustees and functioning for one specific goal or purpose will have disappeared from the governmental scene within 20 years. These single-purpose special districts will disappear, not because they were not performing efficiently or effectively, but because regionalized government (the antithesis of special districts) will gain general acceptance, because regional government promises that operational costs will be reduced materially. Regional government promises to consolidate like functions, such as water conservation, flood control, water distribution and waste water disposal systems, into super departments with attendant reductions in costs of operation and increased efficiency.

This trend toward the regionalization of certain special function districts will be resisted for obvious reasons. If this resistance toward regionalization of certain special function districts is to be successful, the present concepts, about vector control agencies in particular, must be changed.

The concept that untrained, unskilled workers can be employed as mosquito or vector control workers must be eliminated. The certificated, non-scientific and non-technically-oriented personnel must be discarded. The concept that agencies such as mosquito abatement districts are a one-function single-purpose program must be immediately discarded, even if it means changing the name of the present organization of the CMCA and of mosquito districts. Emphasis must be given to the concept that staffs of mosquito abatement districts are technically qualified, environmentally-concerned protectors of the public's health by reason of the vector-control programs administered and developed under their guidance.

My final comment is directed toward the present concern over the failure of pesticides to control mosquitoes and the resultant thought that, because of this temporary setback, mosquito control agencies must resort to legal concepts known as "abatement proceedings". In my opinion, this philosophy will only hasten the day when regional government will absorb programs such as ours! I firmly believe that we must restate our resolve to remain a service-oriented agency, dedicated to the idea that we provide public health protection from vector-borne diseases, because we have the technical skills and competency to resolve vector control problems by direct application -- not by legal abatement notices.

INCOMING PRESIDENT'S MESSAGE

Ronald L. Wolfe
Goleta Valley Mosquito Abatement District
Post Office Drawer 460, Goleta, California 93017

One of the primary reasons for the annual meeting of the California Mosquito Control Association (CMCA) is to present papers and elicit discussions on mosquito control problems, and to share information and ideas on all levels and facets of our operations. During the past two and one-half days we have heard approximately 100 presentations about the problems, accomplishments and objectives of mosquito control agencies throughout the United States. The formal setting for this active exchange has come to a close for another year. But even though we leave with more than we came with and even though we have had a good time, it is not like Christmas –– Santa Claus is not going to take care of our problems. When we return home we will be faced with the same problems that we had when we came although we will have more information on how to solve them. When we get home we will still have resistance and legislative problems. Regional government will continue to be a threat. Research is still going to be needed. Certification will still be a question. Encephalitis will be a disease threat and public relations will be something we think about. But without these problems there would be no need for our Association or our districts. The laws we operate under expect that we will accomplish our charge while adhering to the obligations of proper administration of personnel and tax dollars.

I have a great deal of pride in the people and the accomplishments of this Association and I have great faith in our future. I sincerely doubt that the challenges of 1972 are any greater or lesser than the challenges we faced in 1942, 1952 or 1962. The only difference is that those challenges have been met and won. Because of the California Mosquito Control Association, we have knowledge of those past years and can profit from our experiences. Our Association is the backbone of the achievements in mosquito control in California. It is our primary resource in serving the public of California. Our Association is essential––but like our own districts it has its problems.

I have debated mentally about how forth-right one should be in discussing these situations and have decided it is only fair that everyone know my position:

First, there are petty individual jealousies which restrict the accomplishments of this Association. I believe we should all be working towards the betterment of our Association, and these petty personality differences will not be tolerated.

Second, I feel the bickerings about our Association financing are ludicrous. Association dues are essential to accomplish our objectives. My own district pays more to the California Special Districts Association than it pays to the California Mosquito Control Association and gets less for it. The Water District in Goleta Valley pays $1,800 per year to be a member of its association. The Sanitary District pays $1,300 per year. There is a very small Cemetary District which pays $75 a year. I realize there is a great diversity of opinion in this area; but I still see no reason why, with proper record keeping and sound financial management, we cannot set our goals for success, and our dues, as necessary. Let's get out of the Dark Ages. It costs money to produce and if we believe it's in the best interest of mosquito control and the best interest of the people we serve, we should do it. It is about time we decided what we are going to do and how we are going to do it.

Which brings up the matter of resistance, research and legislation. People have talked about resistance for years and yet we are no further ahead than we were several years ago. I find it interesting that few districts are really as concerned about resistance as the issue would seem to indicate. This was pointed out very poignantly at the Monday afternoon session. If resistance really is a problem, why aren't we telling our story. Why aren't we getting more support?

One reason is that we are not effective in the legislature. I doubt very seriously that any one of you would give your entomologist a microscope and tell him to do his job or that you would give an untrained individual a jeep and tell him to go kill mosquitoes. I think it is just as futile to send one of our people into the halls of the legislature to try to do the job he was sent to accomplish. Our failures in this area speak for themselves. I sincerely believe it is time for us to set our goal and employ assistance to obtain it––if we really do believe we need it.

I also believe it is time for us to meet our legislators and tell our story. If we were to have an epidemic in the State of California that could have been prevented if we had had the research funds necessary, none of us would be able to sleep if we hadn't done everything possible to preclude it.

There has also been a great deal of interest and study about regional government. It is as different in the North and South of the State as is resistance. Just like resistance, however, it is spreading and I am sure it is going to affect all of us. I think it is fortunate that the district that has been hit the hardest happens to be one of the giants of our Association and has done an admirable job in coping with it. How many of us could say the same thing if we were affected next. Unfortunately, many people feel that the mosquito problem is about as big as the insect itself. But then whose fault is that? If we told others outside our profession about what we have been talking about these past two and one-half days, we wouldn't have this problem. If we told others about the monster that we seem to think we are fighting they wouldn't want our job unless they felt we were not doing it properly or were unqualified to hold our positions.

This brings up the matter of expanded scope and certification of employees. The first item I hope to explore in depth. The second I will not discuss now because I hope to make it a reality in 1972. I have many other ideas that will be presented at a later date. I have been in mosquito control for about ten years and do not realize that some things cannot be done. I hope I have stirred up some thoughts in your minds. In closing I want you to remember the objectives of the California Mosquito Control Association. They are: to promote cooperation among those directly and indirectly concerned with and interested in mosquito control and related subjects; to stimulate the development of improved methods and techniques and to disseminate information in relation thereto and to aid in the advancement of this field in California and elsewhere.

We have the resources. We need the motivation. Let's unite our efforts and turn our goals and objectives into our accomplishments for 1972.

MOSQUITO ADULTICIDES AND LARVICIDES, EFFICACY UNDER FIELD CONDITIONS AND EFFECTS OF LARVICIDES ON NONTARGET INSECTS[1]

Mir S. Mulla[2], Robert D. Sjogren[3] and Jorge R. Arias[2]

Recently, mosquitoes in California have become highly resistant to most currently used and some of the experimental organophosphorus insecticides (Georghiou 1970; Schaefer and Wilder 1970). There are indications of a low to moderate level of cross-tolerance to some of the OP and organocarbamate insecticides such as Dursban® and Chevron RE-11775 which have not been extensively used or registered yet for mosquito control (Schaefer and Wilder 19-70). It seems that the life expectancy of most newer OP and OC mosquito larvicides is no longer greater than two or three years as suggested by Mulla (1968).

To overcome these difficulties, emphasis was placed on studies to evaluate materials which will be less prone to the development of resistance. These include the pyrethroids (natural and synthetic), which were tested for adulticidal and larvicidal activity. Several new organophosphates and other compounds were also evaluated for biological activity against mosquitoes. In the course of studies on larvicidal efficacy, the numbers of aquatic nektonic insects were also assessed to see if these treatments caused any reduction in their population density.

METHODS AND MATERIALS.–Adulticides — SBP-1382 or NRDC 104 or NIA 17370 [(5-benzyl-3-furyl)methyl 2, 2-dimethyl-3-(2=methyl propenyl) cyclopropanecarboxylate-(approx. 70% trans, 30% cis isomers)] was evaluated as aqueous or oil spray against adult *Aedes nigromaculis* (Ludlow) in irrigated pastures. Emulsifiable concentrate and concentrate solutions of this material were employed. In the aqueous spray form, the emulsifiable concentrate was used. Pyrethrins (EC 1.6) and piperonyl butoxide were applied in polypropylene glycol or petroleum oils. The sprays were applied by various aircraft to fields in Rancho Santa Maria and other irrigated pastures in Kern County, California, using various amounts of liquid spray per acre.

Two petroleum hydrocarbons (Toxisol FLC), known as ARCO Larvicidal Oil (Atlantic Richfield Co.) and Klear Oil (Witco Chem. Co.) were used as extenders. Both oils are commercially available and are characterized with high boiling ranges.

Larvicides. ––Standard emulsifiable concentrate, concentrate solution, emulsifiable concentrate stabilized for longevity (LLX) and for alkaline conditions (Alk.), and micronized and standard wettable formulations of SBP-1382 were employed for larval control in various locations. The materials were applied either by pressurized hand sprayers or by means of small (one pint) triggered all-purpose household sprayers.

The remaining larvicidal materials with the exception of Phosvel® (VC-605) were evaluated in experimental ponds located at Midgeville (University of California Campus, Riverside) and Oasis (in the Coachella Valley of Southern California). The same techniques of application and evaluation were used as those for SBP-1382.

The percent reduction of third and fourth stage larvae was calculated from counts (five dips per plot or pond) taken before and one, two or seven days post-treatment. Each treatment was replicated twice, and check ponds were sampled concurrently with the treatments to get some idea about the breeding trends of mosquitoes in the experimental ponds.

In addition to SBP-1382, the following materials were evaluated in these studies:

Allethrin: 2-allyl-4-hydroxy-3-methyl-2-cyclopenten-1-one ester of 2,2-dimethyl-3-(2-methylpropenyl)-cyclopropane carboxylic acids.

Dimethrin: 2,4-dimethylbenzyl 2,2-dimethyl-3-(2-methyl= propenyl) cyclopropanecarboxylate.

Pyrethrins: from plant species composed of pyrethrin I, II, cinerin I, II.

Galecron®: N'-(4-chloro-o-tolyl)-N,N-dimethyl= formamidine.

Phosvel®: (VCS-506) O-(2,5-dichloro-4-bromophenyl) o-methylphenylthionophosphonate.

RE-11775: m-sec butylphenyl N-methyl N-phenylthio carbamate.

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[1]Studies conducted in cooperation with the Kern and Coachella Valley Mosquito Abatement Districts. The assistance of H. A. Darwazeh, Bureau of Vector Control and Solid Waste Management in portions of these studies is duly acknowledged.

[2]University of California, Department of Entomology, 134 Entomology, Riverside, California 92502.

[3]Kern Mosquito Abatement District, Post Office Box 1271, Bakersfield, California 93302.

RESULTS AND DISCUSSION.–Adulticidal Studies.—1970 test.—In 1970 studies, the adulticides were applied to irrigated pastures where adult mosquitoes were resting. Efficacy was assessed by taking body landing counts before and at intervals after treatment. Counts in untreated fields were not taken during 1970 studies. In a preliminary test, SBP-1382 or NRDC-104 (40% concentrate) was diluted with ARCO larvicidal Oil and applied at the rate of 0.1 lb/acre of SBP-1382 in 0.5 gallon oil per acre to pastures in Kern County. About 30 acres of an irrigated pasture infested with *A. nigromaculis* were treated with aircraft flying at 15 ft. height, with an effective swath width of 60 feet. The pasture was ¼ mile long, having a pre-treatment count of 41 adults landing on the lower extremities per man. Within one hour post-treatment, there was 100% reduction in the biting rate of adult mosquitoes. This level of reduction continued up to 24-hours post-treatment beyond which observations were discontinued. Larvae of *A. nigromaculis* present in the same pasture suffered 70% reduction 13-hours post-treatment.

In another test conducted in Rancho Santa Maria pastures in Kern County, a 40-acre field was treated with a reduced rate (0.05 lb/acre) of SBP-1382 applied in 0.5 gal of ARCO Larvicidal Oil per acre by air. Almost complete control of adult mosquitoes was achieved within an hour after treatment (Table 1). The level of control was still high, 24 hours after treatment.

Table 1.–Suppression of adult *Aedes nigromaculis* mosquitoes in an irrigated pasture with aerial application of SBP-1382 (EC_2) at the rate of 0.05 lb/acre in 0.5 gallon ARCO Larvicidal Oil/acre (Field 72, Rancho Santa Maria, Kern Co., California, August 27, 1970).[a]

Time of Day	Pre-treatment or hours Post-treatment	avg. no.[b] landing/ minute	Percent Percent reduction
8:30 AM	Pre-treatment	23.0	
9:15 AM	0.5 hr. post	0.4	99
9:45 AM	1.0 ' '	0.2	99
8:30 AM	24.0 ' '	2.7	88

[a]Treated by Cal-Air plane, breeze 2-5 mph from NW. Swath width 60 feet.

[b]Landing or biting counts were taken in various locations of the field for one minute and counting the female mosquitoes which landed on the lower extremities. At least 20 counts were taken during each period.

A series of additional tests were run in Rancho Santa Maria pastures, treating over 1000 acres of infested fields with various dosages of SBP-1382 and volumes of application. Relatively large acreage was treated; but due to heavy populations of adult mosquitoes in the adjacent fields, long-lasting suppression of adults in the treated fields was not expected.

In the first test (Field 16A) where SBP-1382 at the rate of 0.008 lb/acre was applied in 0.5 gallon RLO/acre, excellent control was achieved up to 24-hours post-treatment beyond which observations were discontinued (Table 2). Using the same rate of SBP-1382 but reducing volume per acre to 0.25 gal, (Field 18) good initial control was achieved. The level of suppression, however, dropped to 40%, 24 hours later. This could be due to invasion of the treated field by mosquitoes from adjacent fields. Another experiment (Field 16B) employing 0.01 lb/acre of SBP-1382 in 0.25 gal/acre of RLO also gave excellent initial knockdown of adult mosquitoes. Reducing the volume of application to one pint per acre (Field 17), SBP-1382 at the above rate (0.008 lb/acre) yielded mediocre suppression of adult mosquitoes.

Using water instead of oil as an extender, and increasing the rate of SBP-1382 to 0.025 lb/acre, mediocre suppression of mosquitoes was acheived (Field 59). Even with the increased level of SBP-1382 dosage, suppression of adult mosquitoes was not as good as at the lower rates applied in oil. It thus can be concluded that SBP-1382 seems to manifest increased activity when it is applied in oil instead of water. It is further obvious that the optimum volume of application is in the range of two pints/acre when coarse droplets are produced. Further research on application techniques, optimum droplet size and assessment of meteorologic conditions may enhance the effectiveness of this material at lower volumes.

To show whether RLO was contributing to mosquito knockdown at the rates applied, this oil was applied alone at the rate of 0.5 gal/acre (Field 43). No knockdown was measured within one hour after treatment. Cursory observations elsewhere have shown this oil to produce some control of adult *Aedes* at one gal/acre; further work is needed to elucidate this fact.

1971 Tests.—These tests were initiated to confirm last year's adulticidal efficacy of SBP-1382 and to include pyrethrins plus piperonyl butoxide (furnished by McLaughlin Gormley King Co.).

In the first series of tests, several pastures were treated at the rate of 0.05 and 0.01 lb/acre of SBP-1382, dispensing various volumes of the spray by means of a helicopter having various arrangements of nozzles for dispersal. In the first five fields the level of reduction of adult mosquitoes was quite high (Table 3). The level of suppression in the other three fields was low to mediocre. It is difficult to provide a plausible explanation for this lack of efficacy. It was noted that cotton seed oil as a carrier resulted in very large droplets. The *A. nigromaculis* in the last three fields were highly resistant to organophosphate insecticides. The mosquitoes probably possessed some vigor tolerance that was carried over to the pyrethroid.

In the second series of tests in August, 1971, applications were made with a fixed wing aircraft used in agricultural spraying. Results were quite erratic (Table 4), even though the rate of application was rather similar to the previous series of experiments. The overall level of reduction in these tests was quite low. The adult mosquitoes in these fields are not highly tolerant to other insecticides.

In another test, 40% concentrate of SBP-1382 was evaluated at 0.01 to 0.013 lb/acre at a volume of 32-40 oz/acre using three petroleum hydrocarbons as carriers. The level of control with these coarse sprays was rather low (Table 5) when measured over a period of three to four hours. There was no decline in the biting rate in the check plot over this period.

Another test was accomplished using an emulsifiable concentrate formulation of SBP-1382, applied as ULV in a low

Table 2.–Activity of SBP-1382 in Richfield Larvicidal Oil against adult pasture mosquitoes *Aedes nigromaculis* (9/9-15/70).

Field Number	Area (acres)	Dosage: SBP-1382 lb/ac	Dosage: ARCO LO oz/ac	Time of Application: START	Time of Application: FINISH	Avg. No. of adults landing and (%) reduction: Pre-treat	Post-treatment (Hours) 0.5: No.	0.5: %R	1: No.	1: %R	2: No.	2: %R	24: No.	24: %R
16A	160	0.008	64	0745	0830	570	50	91	35	94	54	90	14	98
18	160	0.008	32	0855	1050	72	10	86					44	40
16B	160	0.010	32	0905	0950	51	5	90						
17	240	0.008	16	1100	120	44			8	80	11	75	30	32
59	160	0.025	64*	0740	0850	54			7	87	13	76	45	17
43	160		0.04	1415	1515	16			19	0				

Field 16A: Fifty-two ounces of (40%) SBP-1382 concentrate mixed with 80 gal Richfield Larvicidal Oil and applied by Cal-air aircraft at the rate of 0.5 gal/ac, using seven T-Jet 8006 fan nozzles, and 20 psi pressure in the system.

Field 18: Fifty-two ounces of (40%) SBP-1382 concentrate mixed with 40 gal of ARCO-LO and applied by air at the rate of 0.25 gal/ac, using four T-Jet 8006 fan nozzles, and 20 psi pressure.

Field 16B: The active material was mixed with ARCO-LO to yield two ounces of (40%) concentrate of SBP-1382/gal, and the solution was applied by air at the rate of 0.25 gal/ac, using four T-Jet 8006 fan nozzles at 20 psi pressure.

Field 17: Sixty ounces of (40%) SBP-1382 concentrate mixed with 30 gal of ARCO-LO and applied by air at the rate of one pt/ac, using eight T-Jet 8001 fan nozzles, and 50 psi pressure.

Field 59: Two gal of SBP-1382 EC_2 mixed with 80 gal of water and applied at the rate of 0.5 gal of spray/ac. Applied by an agricultural spraying aircraft.

Field 43: Fifty gal of ARCO-LO alone were applied by air over 160 acres at the rate of 0.5 gal/ac by an agricultural spraying aircraft.

*Extender water not oil.

Table 3.–Evaluation of SBP-1382 (40% concentrate) against adult mosquitoes (mostly *Aedes nigromaculis*) in irrigated pastures in Kern County, California (August 17-19, 1971).

Field	Treatment time	Area Acres	Carrier	Volume .02	SBP lb/A	Avg. No. Landing: Pre	0.2–0.5: No.	0.2–0.5: % R	3–4: No.	3–4: % R
Jessup N[a]	7:30 - 8:00	160	492 Process oil 42	16	0.01	30	2	93 88		
Jessup S[a]	8:30 - 9:00	160	" "	16	0.005	8	1	100		
Frick & Dennis[a]	10:30 - 11:10	160	" "	16	0.01	2	0	97		
Etcheves[b]	7:00 - 7:12	40	" "	32	0.01	37	1	95	0.5	98
Bloomoff[b] Alfalfa	7:45 - 7:50	20	" "	32	0.01	18	1		0.3	98
Freeborne[b]	9:00 - 9:12	60	ARCO LO	32	0.01	16	5	69	6	62
Portwood[c]	7:30 - 7:34	20	Cotton Seed	6	0.01	75	30	60	40	47
Rancho St. Maria	8:00 - 8:45	320	" "	6	0.01	30	20	34		
Freeborne[d]	9:00 - 9:12	60	ARCO LO	32	0.01	13	6	56		

[a]Helicopter fitted with eight 8002 fan jet nozzles. Pressure 40 lb/in^2. Height of the craft was 25-30 feet. Speed 60 mph. Wind 0-3 during treatment of the first two fields and 5-7 mph during treatment of the third field. Swath 120 feet.

[b]Helicopter fitted with 16 8002 fan jet nozzles. In the last field treated, height too high, too windy for aerial application. Swath 120 feet.

[c]Helicopter fitted with six 8001 fan jet nozzles, altitude 50 feet, wind 5-7 mph. Swath 120 feet.

[d]Helicopter fitted with 16 8002 fan jet nozzles. Wind 5-7 mph. Swath 120 feet.

volatile oil (Klear Oil). Both rates of application (0.005 and 0.01 lb/acre) yielded good to excellent control of adult mosquitoes (Table 6). A correction for decline or increase in the check plot population was made by Mulla's formula (Mulla et al. 1971b) to obtain a better indication of the suppression due to the adulticidal chemical. The corrected values are presented under the column heading MSM, and the uncorrected under N in this and the following tables.

Pyrethrin plus piperonyl butoxide applied in ARCO-LO at 32 oz/acre yielded mediocre reduction at the rate of

Table 4.–Evaluation of SBP-1382 (40% concentrate containing 3.34 lb/gal) against adult *Aedes nigromaculis* in irrigated pastures (Rancho Santa Maria, August 20, 1971).[a]

Field Number	Treatment time	Carrier Oil	oz/A	A. I. lb/A	Avg. no. landing Pre	Avg. no. landing Post-treat hrs. 0.2-0.5	Avg. no. landing Post-treat hrs. 3-4
16	9:30 – 9:50	Process	24	.008	30	8	15
31	9:00 – 9:30 A	Process	24	.008	20	16	20
29	10:00 – 10:30 A	ARCO LO	24	.008	8	2	4
30		ARCO LO	24	.008	52	24	33
Pintail	7:00 – 7:30	Process	32	.02	200	200	200

[a]Fixed wing piper cub with short boom provided with ten 8002 Tee Jet fan nozzles. Wind 4-5 mph, except fields 29 and 30. When wind was 7-10 mph. Altitude 30-50 ft. Nozzles due to rust in tank were clogging. Fields 30 and 31 high Sudan grass and water grass. For fields 29, 30, 31, and Pintail nozzles were five 8002 Tee Jet fan on left side of boom and four 8002 and one 8006 on right side. Swath in all cases 70 feet. Speed of aircraft 80 mph. Each field was 160 acres.

Table 5.–Evaluation of SBP-1382 (40% C) at the rate of 0.01 lb/A and a volume of 0.25 gal/A against adult *Aedes nigromaculis* mosquitoes in irrigated pastures (Rancho Santa Maria, Kern Co., California IX/8-9/71).[a]

Field Number	Acres	Oil	Swath Width (feet)	Time Start	Time Finish	Landing rate (no.) and % reduction post (hrs) Pre No.	1-2 No.	1-2 % R	3-4 No.	3-4 % R
40	160	Sunland		9:18						
		Auto Diesel 1	72	9:18	10:00	37	32	14	10	73
42	160	Process Oil 42								
		(Texaco)	72	10:35	11:10	18	11	39	8	66
35	160	ARCO LO	60	11:22	12:00	26	12	54	11	58
16, 20	400	ARCO LO	90	7:40	9:00	47	16	70		
19	160	Check				80	85		85	

[a]Grass in all pastures very short. Nozzles turned 45° into wind. Altitude 15-25 feet. Cal-Air plane used in all treatments. Field 40 was treated using 12 8004 T-Jet fan nozzles pressure 40 psi.

Fields 42 and 35 were treated with a boom carrying ten 8002 T-Jet fan nozzles, pressure 35 psi. Fields 16 and 20 treated with a boom provided with six D6 nozzles without cores or discs, delivering about 40 oz of volume/A, and 0.013 lb/A of SBP-1382. Check (Field 19) used with test in Fields 16 and 20 only.

0.008 lb/acre of pyrethrins (Table 7). Similar results were obtained with a ULV application using polypropylene glycol 400 (PPG-400) as carrier. The high viscosity of the latter material was undesirable from the standpoint of ease of handling and mixing.

Further studies on the efficacy of pyrethrins as adulticides were conducted, employing ULV applications using a low volatile oil (Klear Oil) as a carrier at both 0.0025 and 0.005 lb/acre of pyrethrins. Good control of adult mosquitoes was obtained within one to two hours post-treatment (Table 8). Here again, the values under MSM calculated by Mulla's formula depict an accurate trend of the adult mosquito populations.

From the foregoing studies, it is apparent that SBP-1382 and pyrethrins show promise for the control of adult mosquitoes. A good deal of research is needed to work out the optimum application equipment producing optimum droplet size and numbers. Further studies on the efficacy of these materials against various species and under different habitat and meteorological conditions will be necessary before these materials can be extensively used in mosquito control. From studies conducted thus far, it is deduced that these compounds will pose fewer hazards to non-target organisms or wildlife at the lower rates of application needed for the suppression of adult mosquitoes.

Larvicides, Efficacy and Effects on Non-Target Organisms

Botanicals and Relatives.—–Various formulations of SBP-1382 were evaluated against mosquito larvae in different breeding sources. The level of larval suppression at 0.1 and 0.2 lb/acre of active ingredients was low. The long lasting EC_2 (LLX), micronized powder and wettable powder formulations, were superior to EC_2 and C_{40} formulations. It is important to note that the long-lasting formulations (EC_2-LLX) yielded better control of mosquitoes than the formulation prepared for alkaline water. Similarly, the micronized WP formulation showed better than the regular WP. In order to improve the larvicidal activity of this material, further studies on formulation techniques are needed.

Table 6.—Evaluation of SBP-1382 ECXY-2 against adult *Aedes nigromaculis* in irrigated pastures (Rancho Santa Maria, Kern Co., California. X/13/71).[a]

lbs/acre SBP-1382	Field Number	Start - Finish	Pre	Post 1 No	Post 1 % Reduction[b] MSM	Post 1 % Reduction[b] N	Post 2 No	Post 2 % Reduction[b] MSM	Post 2 % Reduction[b] N
0.01	77	0840-0900	96	9	90	91	7	84	93
Check	41		27	25			12		
0.005	69	0930-0950	68	14	75	80	7	87	90
Check	41		27	22			22		

Landing rates pre and post (hrs) and control

[a]Cal-Air spray plane provided with 22 800067 fan jet nozzles used. ULV applied at the rate of six oz/A, 160 foot swath. Altitude 30 feet, speed 100 mph, pressure 20 psi, and wind 1-3 mph, with 22 800067 fan jet nozzles. The carrier was Klear Oil.

[b]MSM is calculated by the formula: $\% \text{ Reduction} = 100 - \left(\frac{C_1}{T_1} \times \frac{T_2}{C_2}\right) 100$; Where: C_1 = avg. no. adults pre-treatment in check plots; T_1 = avg. no. adults pre-treatment in treated plots; C_2 = avg. no. adults post-treatment in check plots; T_2 = avg. no. adults post-treatment in treated plots. N is calculated by the formula; $\% \text{ Reduction} = 100 - \left(\frac{T_2}{T_1}\right) \times 100$ Where T_1 and T_2 are the same as in the MSM formula.

Table 7.—Evaluation of pyrethrins plus piperonyl butoxide against adult *Aedes nigromaculis* in irrigated pastures (Rancho Santa Maria, Kern Co., California. IX/22/23/71).[a]

Pounds/Acre Pyrethrins	PBO	Field Number	Aircraft	Start-Finish	Carrier	Pre	Post 1 No.	Post 1 %R MSM	Post 1 %R N	P Post 2 No.	P Post 2 %R MSM	P Post 2 %R N
0.008	0.04	20	Pawnee[b]	0833-0910	ARCO-LO	153	40	64	74	56	43	73
Check		35				125	90			80		
0.008	0.04	18	Pawnee[b]	0940-1015	ARCO-LO	137	35	71	74	28	77	80
Check		35				90	80			80		
0.005	0.025	34	Cal-Air[c]	0802-0817	PPG 400[d]	59	18	69	69	11	69	80
Check		35				100	100			85		
0.01	0.05	18	Cal-Air[c]	0852-0910	PPG 400[d]	109	27	71	75	13	70	88
Check		35				100	85			40		

Landing rates (no.) pre and post (hrs.)

[a]Fields 20 and 18 were treated on September 22 while Fields 34 and 18 were treated on September 23. Wind was 1-3 mph.

[b]Provided with nine 8004 fan jets--Swath was 60 feet. Altitude 15 feet. Speed 90 mph, 35 psi. Rate 32 oz/acre.

[c]This was ULV application, delivering six oz/acre based on 160 foot swath. Altitude 30 feet. Speed 100 mph, 20 psi. Provided with eight 8002 fan jets.

[d]Polypropylene glycol 400.

Pyrethrins and allethrin with 2x piperonyl butoxide, produced moderate to low levels of larval suppression at 0.1 and 0.02 lb/acre rates, when the concentrates were applied as aqueous sprays. Dimethrin containing an equal amount of piperonyl butoxide yielded good control of larvae at 0.1 and 0.2 lb/acre rates, but more recent formulations have not yielded the same results in repeated tests. At lower rates (0.01-0.05 lb/acre) this formulation applied as oil or aqueous spray did not yield any appreciable level of larval reduction. Dimethrin at 0.1 lb/acre when applied in 0.25 and 0.5 gal/acre of Toxisol FLC, yielded excellent control of mosquito larvae, but again these results have not been duplicated in subsequent tests. Similarly, pyrethrins and allethrin at 0.1 lb/acre applied in 0.25 and 0.5 gal/acre of Toxisol FLC yielded excellent control.

From these studies it is apparent that pyrethrins and allethrin can be made more effective if they are applied as oil sprays instead of aqueous sprays. Due to the variable content of isomers in various commercial batches, activity will probably vary somewhat from time to time. Further studies on these materials as larvicides are warranted before their efficacy can be clearly demonstrated.

Other Synthetic Compounds.——GALECRON® at 0.2 lb/acre yielded good control of mosquito larvae (Table 9). Phosvel at 0.05 and 0.1 lb/acre also gave excellent control of pasture mosquitoes (*A. nigromaculis*). Fenthion, formu-

Table 8.–Evaluation of pyrethrin plus piperonyl butoxide against adult *Aedes nigromaculis* in irrigated pastures (Rancho Santa Maria, Kern Co., California X/12/71).[a]

				Landing rates (no.) pre and post (hrs.) and control						
					Post 1			Post 2		
lbs/acre		Field	Time		% Reduction[b]			% Reduction[b]		
Pyrethrins	PBO	Number	Start - Finish	Pre	No	MSM	N	No	MSM	N
0.0025	0.0125	43	0910-0930	124	46	68	63	25	77	80
Check		41		35	40			30		
0.0025	0.0125	44	0910-0930	164	59	69	64	25	82	85
Check		41		35	40			30		
0.005	0.025	68	1020-1040	158	37	69	77	15	81	91
Check		41		40	30			20		
0.005	0.025	67	1020-1040	76	28	51	63	22	42	71
Check		41		40	30			20		

[a]ULV treatments as six oz/A, 160 foot swath. Altitude 30 feet, speed 100 mph, pressure 20 psi, and wind 1-3 mph. Cal-Air aircraft provided with 22 800067 fan jet nozzles. The carrier for the formulations was Klear Oil.

[b]MSM calculated by the formula: % Reduction = $100 - \left(\frac{C_1}{T_1} \times \frac{T_2}{C_2}\right) 100$ Where: C_1 = avg. no. adults pre-treatment in check plots; T_1 = avg. no. adults pre-treatment in treated plots; C_2 = avg. no. adults post-treatment in check plots; T_2 = avg. no. adults post-treatment in treated plots.

N calculated by the formula: % Reduction = $100 - \left(\frac{T_2}{T_1}\right) \times 100$ where T_1 and T_2 are the same as in the MSM formula.

Table 9.–Evaluation of various mosquito larvicides in various breeding sources against *Culex* species (1970).

Material	Formulation	lbs/a	Carrier gal/a	1-7 days & Red.	Location
Galecron	EC_4	0.1	Water 1	0	Oasis ponds
		0.2		90	Oasis ponds
Phosvel (VCS-506)	EC_3	0.05	Water 8	100	Pasture
Fenthion	Capsules 23%	0.6		90	Midgeville Ponds
RE-11775	EC_2	0.01	Water 5	84 84	Midgeville Ponds
		0.05		98	Midgeville Ponds
		0.10		96	Midgeville Ponds

lated in capsules, did not yield complete control at 0.6 lb/acre. Under these conditions this material usually produces complete control at the rate of 0.1 lb/acre. It is possible that the larvicide was not released adequately from the capsule to yield complete control.

A new carbamate insecticide, Chevron RE-11775, yielded excellent control of larvae at 0.05-0.1 lb/acre. This material shows promise for the control of resistant mosquitoes (Schaefer and Wilder 1970), but is possibly subject to the same fate as the synthetic OP compounds to which *A. nigromaculis* mosquitoes have acquired a high level of tolerance.

Effects on Non-target Insects.—–Effects of various materials and formulations on diving beetle larvae and adults, mayfly naiads, and dragonfly naiads were studied as before (Mulla and Darwazeh 1971a, b; Mulla et al. 1971a). Damselfly naiads prevailed in low numbers, thus their numbers could not be subjected to any interpretation.

Diving beetle larvae and adults occurred in very low numbers as sampled by the "dip" sampling technique. It is not easy to make any definite conclusions regarding the numbers of these in the various treatments. In general it can be said that SBP-1382 did not reduce the populations of these insects to any great extent (Table 10), but further work is needed to establish such a correlation.

Mayfly naiads were apparently affected by the various applications of SBP-1382. Similarly, pyrethrins, allethrin and dimethrin, adversely affected the populations of mayfly naiads. Dragonfly naiads were not markedly affected by SBP-1382 and recovery was somewhat slower at the higher rate, but faster at the lower rate of 0.1 lb/acre. The other pyrethroids had little if any effect on dragonfly naiads.

Mayfly naiads seem to be the weakest group of the aquatic non-target insects responding to various pesticidal treatments. Even the relatively less hazardous materials such as the pyrethroids could reduce populations of these aquatic insects. Mayfly naiads are mostly herbivores and play an important role in the abundance of filamentous algae. Removal of these herbivores may lead to heavy growth of these algae.

Table 10.–Effects of various pyrethroids (natural and synthetic) on the population trends of nektonic insects in mosquito breeding ponds (Oasis, California, 1970).[a]

Material and	Extender	Dosage	Diving beetle L and A			Mayfly naiads			Dragonfly naiads		
Formulation	gal/a	lb/a	Pre	2	7	Pre	2	7	Pre	2	7
SBP-1382 EC_2	Water 3	0.05	2	1		18	2		3	1	
	"	0.10	4	0		7	0		3	1	
	"	0.20	2	1		22	0		1	1	
Check			3	0		23	5		3	1	
SBP-1382 EC_2 (Alk) (Alk)	Water 1	0.10	2	0	4	90	1	2	6	3 0	5 6
	"	0.20	1	1	5	78	2	12	1	0	22
SBP-1382 EC_2 (LLX)	Water 1	0.10	0	1	1	93	4'	0[b]	0	0	0[b]
	"	0.20	4	1	3	140	2	0[b]	9	1	
Check			0	1	2	91	125	119	0	3	4
SBP-1382 10 WP	Water 5	0.1	2		2	134		0	8		8
micronized	"	0.2	4		0	8		0	8		9
SBP-1382 10 WP	"	0.1	3		2	121		0	16		11
	"	0.2	4		2	65		0	3		3
Pyrethrins EC17%	Water 1	10.1	2		1	76		0	4		9
Allethrins EC9%	"	0.2	4		1	17		0	26		6
+Pip butox 18%	"	0.1	1		0	61		6	22		39
	"	0.2	2		0	41		0	19		8
Dimethrin 50%	"	0.1	1		1	64		8	67		14
+Pip butox 50%	"	0.2	3		2	156		14	12		10
Check			2		2	1		1	1		2
Dimethrin 50%	Tox FLC 0.5[c]	.01	1	3	0	0	0	0	12	6	6
+Pip butox 50%	0.5	.05	1	1	0	0	0	0	14	21	29
	Water 1.0	.05	2	7	8	8	1	0	3	1	10
Check			2	1	3	3	0	1	6	4	6
Pyrethrins EC17%	Tox FLC 0.25[c]	0.1	1	0	3	3	0	0	13	16	17
	" 0.50	0.1	0	0	0	0	48	50	16	7	17
Dimethrin 50%	" 0.25	0.1	0	1	0	0	1	1	24	25	31
+Pip butox 50%	" 0.50	0.1	2	1	1	0	0	0	5	6	10
Allethrin 9%	" 0.25	0.1	3	1	0	1	15	3	15	13	15
+Pip butox 18%	" 0.50	0.1	3	0	1	20	ÐO	1	26	27	10
Check	"		1	2	1		16	12	6	8	13

[a]Galecron EC_2 applied at 0.1 and 0.2 lb/acre as aqueous spray did not adversely affect populations of dragonfly naiads or diving beetle larvae and adults. Also SBP-1382 EC_2 at 0.05, 0.1 and 0.2 lb/acre did not adversely affect populations of Dixa midge larvae, nor diving beetle larvae and adults. Similarly RE-11775 EC_2 at the rate of 0.1 lb/acre did not affect the latter two groups of insects adversely.

[b]Populations of these insects recovered appreciably two weeks after treatment except in these dosages.

[c]FLC contained a nonionic surfactant PL-121 at 1% concentration.

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