PROCEEDINGS AND PAPERS

of the

Thirty-Seventh Annual Conference of the California Mosquito Control Association, Inc.

held at the

INTERNATIONAL HOTEL

LOS ANGELES, CALIFORNIA

JANUARY 27-29, 1969

Edited by

Thomas D. Peck

Business Office

CALIFORNIA MOSQUITO CONTROL ASSOCIATION, INC.

W. Donald Murray, Secretary-Treasurer

1737 West Houston Avenue

Visalia, California 93277

Published January 22, 1970

CMCA Press – Visalia, California 93277

1969 CORPORATE MEMBERS OF THE CALIFORNIA MOSQUITO CONTROL ASSOCIATION

Alameda County Mosquito Abatement District
Antelope Valley Mosquito Abatement District
Borrego Valley Mosquito Abatement District
Butte County Mosquito Abatement District
Carpinteria Pest Abatement District
Coachella Valley Mosquito Abatement District
Coalinga Huron Mosquito Abatement District
Colusa Mosquito Abatement District
Compton Creek Mosquito Abatement District
Consolidated Mosquito Abatement District
Contra Costa Mosquito Abatement District
Del Norte County Flood Control District
Delta Mosquito Abatement District
Diablo Valley Mosquito Abatement District
Durham Mosquito Abatement District
East Side Mosquito Abatement District
El Dorado County Health Department
Fresno Mosquito Abatement District
Fresno Westside Mosquito Abatement District
Glenn County Mosquito Abatement District
Goleta Valley Mosquito Abatement District
Humboldt - Del Norte County Health Department
Inyo County Health Department
Kern Mosquito Abatement District
Kings Mosquito Abatement District
Lake County Mosquito Abatement District
Los Molinos Mosquito Abatement District
Los Angeles County West Mosquito Abatement District
Madera County Mosquito Abatement District
Marin County Mosquito Abatement District
Merced County Mosquito Abatement District
Moorpark Mosquito Abatement District
Napa County Mosquito Abatement District
Northern Salinas Valley Mosquito Abatement District
Northern San Joaquin County Mosquito Abatement District
Northwest Mosquito Abatement District
Orange County Mosquito Abatement District
Sacramento County - Yolo County Mosquito Abatement District
San Joaquin Mosquito Abatement District
San Mateo County Mosquito Abatement District
Santa Clara County Health Department
Shasta Mosquito Abatement District
Solano County Mosquito Abatement District
Sonoma Mosquito Abatement District
Southeast Mosquito Abatement District
Sutter - Yuba Mosquito Abatement District
Tehama County Mosquito Abatement District
Tulare Mosquito Abatement District
Turlock Mosquito Abatement District
West Side Mosquito Abatement District

1969 SUSTAINING MEMBERS
CALIFORNIA MOSQUITO CONTROL ASSOCIATION

Sustaining Members will be those individuals and/or organizations who desire to contribute to the furtherance of mosquito control through this Association.

ALCO CHEMICAL COMPANY
Charles D. Allen, President
Dean Leedham, Technical Director
Ron Richardson, Sales Representative
19220 Pioneer Blvd.
Artesia, California 90701

AMERICAN CYANAMID COMPANY
Franklin Allen, District Manager
2150 Franklin Street
Oakland, California 94612
Robert J. Pace, Sales Representative
2516 Andover Place
Costa Mesa, California 92626

ATCO, PAWNEE DIVISION
Les Jones, Manager
2215 S. Terrace Avenue
Visalia, California 93277

CAM CHEMICALS
Keith Hutchison, Manager
P.O. Box 295
Tulare, California 93274

CHEMAGRO CORPORATION
G.C. Bryars, Regional Sales Manager
1400 N. Harbor Blvd., Suite 228
Fullerton, California 92632

CONTROLLED AIRSTREAMS
Roy McBride, President
P.O. Box 1242
Gardena, California 90249

COX DISTRIBUTING COMPANY
Richard C. Dale, Sales Manager
S.G. Saltus, Vice President
2207 S. Main Street
Los Angeles, California 90007

DOW CHEMICAL COMPANY
R.S. Braucher, Account Manager
2600 Wilshire Blvd.
Los Angeles, California 90054
B.B. Daily, District Sales Manager
350 Sansome Street
San Francisco, California 94106

DURHAM CHEMICAL COMPANY
Jack Prieur, Sales Representative
4124 E. Pacific Way
Los Angeles, California 90023

HUGHES TOOL COMPANY – AIRCRAFT
Jim B. Gustafson, Aerial Applic. Mgr.
Centinela & Teale Streets
Culver City, California 90230
Ralph E. Mitchell, Western Division Mgr.
3205 Lakewood Blvd.
Long Beach, California 90808

HUMBLE OIL & REFINING COMPANY
R.C. Fraser
1800 Avenue of the Stars
Los Angeles, California 90067

INTERNATIONAL HARVESTER COMPANY
J. Morgan, Sales Promotion Supervisor
530 N. Baldwin Park
Industry, California 91744
Kenneth Fox, Fleet Sales man
1110 E. Katella
Anaheim, California 92805

KAISER JEEP SALES CORPORATION
H.H. Crist, Jr., Fleet Sales Manager
940 N. Cove Blvd.
Toledo, Ohio 43601
R.E. Creger, Regional Manager
185 Valley Drive
Brisbane, California 94005

LOS ANGELES CHEMICAL COMPANY
H.W. DeVries, Manager Contract Sales
4545 Ardine Street
South Gate, California 90280

MANITOU EQUIPMENT COMPANY
F.G. Beukers, Sales Representative
P.O. Box 1236
Redwood City, California 94064

MCKESSON CHEMICAL COMPANY
Roy H. Overby, Branch Manager
4729 E. Commerce Avenue
Fresno, California 93745

MOYER CHEMICAL COMPANY
Kenneth D. Gillies, Vice President
P.O. Box 945
San Jose, California 95108

NIAGARA CHEMICAL DIV., FMC CORPORATION
W.H. Wade, Mgr., Tech. Serv. & Product Promotion
P.O. Box 1669
Fresno, California 93717

OCCIDENTAL CHEMICAL COMPANY
Lou W. Grabe, Entomologist – Tech. Services
P.O. Box 198
Lathrop, California 95330

THIOKOL CHEMICAL CORPORATION
Wayne R. Pugmire, Mgr. Com. Sales
P.O. Box 403
Logan, Utah 84321
John Rutledge, Sales N. Calif. & W. Nevada
940 Elverta Road
Elverta, California 95626

WOLVERINE WESTERN CORPORATION
John Blake, Jr., Vice President - Marketing
875 West 16th Street
Newport Beach, California 92660

TABLE OF CONTENTS

California Mosquito Control Association

WHAT WE KNOW AND DON'T KNOW ABOUT MOSQUITO CONTROL

James B. Kendrick, Jr.

Agricultural Sciences
University of California, Berkeley

First, I think I should say something that everybody in California ought to know. I believe very few people really picture how many mosquitoes we would have in California if we did not have a superb mosquito control operation going right now. We probably could not sleep at night in most of California. Just going outdoors could be uncomfortable and even dangerous. So, I am speaking for a lot of people – just about all Californians, whether they know it or not – when I say to our mosquito abatement districts and their staffs: "We know one thing about mosquito control; we are glad you are here."

We have learned some other things about mosquito control in California. We know that nature has given us a warning that future mosquito research is not going to be easy or cheap. We know that the logic of chemical pest control demands more specific chemicals. But we also know that the more specific a chemical is, the more limited its use, the more costly it is for the chemical industry. Costs are becoming almost prohibitive. So, when our research people talk about new approaches, they mean really new.

The warning from nature came just a couple of months ago. Dr. Charles Schaefer, at the University's Mosquito Control Research Laboratory in Fresno, reported that the little pasture mosquito known as *Aedes nigromaculis* is now resistant to every insecticide on the shelf. Even some new ones not yet on the market will not touch it. We are lucky, of course, that, as far as we know, this little mosquito does not carry any diseases of man or animals. It is a pest, as Valley residents know very well, but not a potential killer. However, that near-total resistance reminds us that we are on borrowed time with more dangerous mosquitoes. We have gone through a lot of insecticides in the last 20 years, and we are approaching what looks painfully like a dead end.

We have come to a very sharp turn, at least. Killing mosquitoes with chemicals is becoming prohibitively expensive. Partly, this is because mosquitoes are getting more resistant to insecticides. But it is also because people know more about chemicals today, and they are increasingly reluctant to have poisonous and persistent chemicals used in their environment. So regulations have become more stringent. Developing chemicals that comply with these regulations cost more. Ten or 15 years ago it cost less than half a million dollars to get a new insecticide on the market. The same development job today costs from three to five million dollars. It is fairly obvious that putting three million dollars into developing a single-purpose insecticide to kill a specific pest, with just that one possible market, is not an attractive business proposition.

On first thought, this seems to suggest that the outlook is dim for future chemical control of mosquitoes. But I do not think we can dismiss chemicals that quickly. Dr. Ray Smith suggests that the future is more likely to see some new, broader approaches to chemical control. Dr. Mir Mulla suggests that we look for wholly new lines of chemicals, compounds with different modes of action from those we are using, perhaps even a compound that is really resistance-proof, even if it is less effective and more expensive.

While I cannot look at this as an entomologist, I can look at research as a plant pathologist and an administrator. I know that creating new chemicals is a sophisticated area of research, time consuming and costly, I know that we will need all the time we have. We will have to conserve today's effective mosquito control chemicals by cautious use while we search out new compounds and less extravagant methods of using them.

So, in our laboratories at Riverside, Berkeley, Davis and Fresno, what can we see ahead? We can see some ideas that might sound like wild dreams to an outsider. The use of fish is one instance – fish that will live in heavily polluted water and eat mosquito larvae. Plants may come to the aid of man by poisoning the water in which mosquito larvae are trying to grow. Diseases of mosquitoes may offer an effective means of control. People, and other animals, have diseases. Why not mosquitoes? And attractants, one of our newest weapons in the arsenal of mosquito control, may be put to work for us.

Just last week, you may have seen a news story from the University's Riverside campus. An attractant has been isolated by a creative young scientist from Japan, Dr. Ikeshoji. It will almost force female mosquitoes to lay eggs in a baited area of water. The promise of attractants challenges scientists to further imagination, to find ways to draw mosquitoes into poisoned ponds where the larvae will die.

Because water is the medium for both mosquito larvae and fish, the challenge to biological control researchers is that of getting the two together. Biological control has to concentrate on the larval stage. Dr. Ernest Bay at Riverside reminds us that if we could find a biological control at the adult stage of the mosquito – such as a bird, the control might become as much a problem as the pest. His interest is in a little fish most of us know best in the home aquarium. The little guppy shows real promise, he says. Some strains can tolerate extremely polluted waters where mosquito larvae thrive. Early in the season, the mosquitoes might get ahead because it does not look as if guppies can survive California winters. It may be necessary to spray early in the season while a new crop of guppies is multiplying, but later the fish should take over.

Some other ideas that might have sounded "far out" a few years ago are looking better today. Fungi and bacteria, for instance. Eldon Reeves points out that other insects are afflicted with some fatal diseases. Bees succumb by millions to foul brood. The pathogens of mosquitoes deserve a lot more exploring.

There is a lot more exploring to do in the natural habitats of mosquitoes. Dr. Reeves reports increasing promise in the use of algae that produce toxins that will kill mosquito larvae. He is now extracting and studying the toxins, and considering how to introduce these toxic algae into waters where mosquitoes lay eggs.

These complex lines of attack bring us to the overall aims of University research on mosquito control on three campuses and at the Fresno laboratory. On the campuses we tend to seek out the long-range approaches. That is where our people are searching for the completely new areas – the guppies, mosquito pathology, the attractants, and algae. These research efforts involve a vast investment of time, but they are our foundation. This is the mission-oriented basic research we talk about. Without it, there would be nothing to apply.

In 1967, on the advice of our mosquito control advisors, we made some changes in the program at the Fresno laboratory. Its research since then has been pointed more toward immediate needs of mosquito abatement districts. The program set up by Dr. Schaefer necessarily covers a wide area to meet those needs. This includes work on use of current insecticides – how to use them effectively, and what happens to them in the mosquito's habitat, where the chemicals go and how long they persist, and what they may do to mosquito predators that might be helping out on the control job.

Working with the chemical companies, the laboratory has an active program of testing new materials and exploring new and different kinds of chemical actions. Necessarily, a lot of attention is going to that resistant pasture mosquito. Dr. Schaefer tells us that one of the carbamates will control the pest in the adult stage, but controlling adults is not the objective.

In the irrigated pastures new broods of mosquitoes keep coming along almost continuously after every irrigation from April to November. That means about 20 broods a year. Twenty sprayings a year almost guarantee elimination of susceptible insects and selection of a resistant strain. This formula has worked distressingly well. Working with the pasture mosquito in the laboratory has been a real challenge to entomological imagination. The laboratory must have eggs and larvae. These are the stages most effectively controlled. But these little mosquitoes will not breed in a laboratory, at least not willingly. The answer to this has been artificial insemination of mosquitoes. It has worked, and now the lab has *Aedes nigromaculis* eggs.

The Fresno activities do not stop at the laboratory door, of course. The whole agricultural operation of Fresno County is part of the working laboratory. Some experiments are being run on reducing mosquito numbers by water management. These include even chemical treatment of soils to get faster water penetration and to reduce the time water is on the pastures breeding more mosquitoes.

As all of our mosquito control investigators point out, the University tends to get called in on a crisis. Budgets do not increase as crises do. So money, or lack of it, limits study to the more obvious. It is not so easy to find money to initiate new, untried programs. They have high potential for producing no benefits – or no immediate ones. The whole program of mosquito research we have going in the Division of Agricultural Sciences is only part of the program our committee proposed. That is because only part of the program has been funded. Very clearly we now need full funding to expand to the full program.

Fortunately, our more dangerous California mosquitoes are biologically and ecologically different from *Aedes nigromaculis.* They have developed resistance more slowly and control research has kept ahead of them. But the warning resistance in that little pasture mosquito in Fresno County tells us that the threat of resistance in the disease-carrying species is always with us. In 1952 there were more than 700 cases of encephalitis in the Valley. *Culex tarsalis*, the vector, is always present and ready for a takeoff in numbers when conditions are right.

Barely a year ago, the Spiller report declared that "Today, malaria is absent or of negligible incidence and major resurgence is quite improbable". But California's vector of malaria, *Anopheles freeborni*, is always with us. And probably 10% of our half million men in Vietnam are infected with malaria. As they come home, the chances of reinfecting the vector seem very real.

The danger is here now, and, according to Dr. Mulla, our mosquito population may double or triple in the next few years. As Feather River water reaches the west side of the San Joaquin Valley, mosquitoes can be expected to increase in a new area. And we cannot forget urban mosquitoes. They can even breed in swimming pools. Dr. Mulla says a 20 x 20 pool unattended for five days can produce a million mosquitoes. There is no indication that Californians are going to stop building swimming pools.

To summarize these thoughts, I think we can say that what we know for sure about mosquito control is that the problem is not solving itself. We have mosquitoes becoming more resistant to insecticides. We have a rather jarring indicator that our arsenal of mosquito control pesticides is running out. We know the job of the chemical companies in developing new insecticides is a long and costly job. And so is research in learning what the compounds do to mosquitoes, mosquito predators, and to our environment.

We know we are not reducing our sources of mosquitoes. We are bringing irrigation water to new areas, and city areas are growing, with their swimming pools, and lawns, and puddles. We know that a vast amount must be learned about mosquito species themselves and their ecology. We know we will have to pursue new directions, create chemicals that work differently, and work out methods of using them that halt or slow the process of resistance. We need the help we can get from nature's own parasites, predators and pathogens.

We know the mosquito is more than an annoying, biting insect. The danger of mosquitoes as vectors of deadly disease is still hanging over us. We know the need is urgent for more research knowledge to back up the excellent mosquito control job now being done, and the need for funds to expand mosquito control research is urgent. Finally, we know that everyone in California – farmer or urbanite – has a stake in effective control of mosquitoes. Comfort and health and even lives depend on it.

EVOLVING CONCEPTS OF ENCEPHALITIS PREVENTION IN CALIFORNIA [1]

William C. Reeves

School of Public Health
University of California, Berkeley

At last year's Conference, I presented the first data in support of an emerging concept that: there is an identifiable threshold level of *Culex tarsalis* population essential to maintain transmission cycles of western equine encephalitis (WEE) and St. Louis encephalitis (SLE) viruses; and that at a higher vector population level one could expect frequent infection of susceptible humans and clinical cases of encephalitis (Reeves, 1968). Data from Kern County indicated SLE virus had disappeared from this region when *Culex tarsalis* light trap indices were still above an average of 10 females per night. However, WEE virus remained active until vector indices were reduced over an extensive area to an average of 1 female per trap night. Clinical cases of these 2 diseases in man and horse virtually disappeared when over the summer light trap indices for urban and suburban areas were reduced to an average of 10 or less female *C. tarsalis* per trap night. These findings created considerable interest as they provided potential targets for control agencies when supported by further observations.

The distribution of confirmed cases of encephalitis in man and horse throughout the state in 1967 coincided generally with the levels of *C. tarsalis* populations that the Kern County studies predicted would result in clinical cases.

I can report additional preliminary findings from Kern County in 1968 that extend our confidence in the previous observations. WEE and SLE viruses were active in Kern County in 1968. WEE virus was first detected in *C. tarsalis* in the week of June 18 and at a time when the light trap index for this mosquito, based on 22 traps scattered over the entire district, had reached an average of 4 females per trap night. In the specific region of viral isolation, 7 traps had indices that ranged from 2 to as high as 17 *C. tarsalis*. SLE virus did not appear until the week of August 5 when the light trap index over the entire district had been at an average level of 16 per trap night for 2 successive weeks. At the specific site where SLE virus was isolated, the light trap index during the week of viral isolation was 53 female *C. tarsalis* per trap night. This was the first detection of SLE virus in 5 years from Kern County.

In 1968, confirmed cases of encephalitis in man occurred in Kern County for the first time in 4 years. The 2 WEE cases had onset dates of July 18 and July 30, a period when *C. tarsalis* indices had risen above 5 per trap night and were rapidly approaching the peak average of 16 per trap night. Five WEE cases were diagnosed in horses, the first with onset of June 29 and the remainder in July. All onsets of equine cases followed the occurrence of light trap indices of 5 or higher. The one human SLE case had a late onset date of October 1, over 1 month after the vector indices for the region had dropped from 16 to 2 or less.

Tests for antibody development in 16 sentinel chicken flocks are still in progress, but in general there was an overall rise in the proportion of birds infected with WEE virus as compared with the 3 previous years. A low proportion of birds developed SLE antibodies. There was no evidence of WEE virus activity in urban Bakersfield, but the virus was active in almost all other areas studied. SLE virus was very focal in distribution and was detected at only 5 of 16 sites studied.

The foregoing detail is given to indicate the general correlation found when an index as crude as the average number of female *C. tarsalis* per trap night over an area of 1,500 square miles for a complete summer is used for correlation with viral activity. Much more detailed analyses must be done on data from specific sites, as we know the highest indices of *C. tarsalis* population and SLE virus activity were distributed focally.

The State Department of Public Health reported again in 1968 that the remaining 8 cases of WEE and 3 cases of SLE

[1] This research was supported in part by Research Grant AI 03028 from the National Institute of Allergy and Infectious Diseases, and General Research Support Grant I-SO-1-FR 05441 from the National Institutes of Health, U.S. Department of Health, Education and Welfare.

in man and 26 WEE cases in horses were largely located in the northern half of the state (Bureau of Communicable Diseases, California State Department of Public Health, 1968).

The basic concept that human cases of WEE and SLE in California can be prevented by *C. tarsalis* control has become established as an integral part of the $9,000,000 investment of tax revenue in over 50 agencies established for mosquito control in this state. We do not doubt that future success in encephalitis prevention will reflect the effectiveness of efforts to minimize populations of *C. tarsalis*. However, this audience must also understand the unknown factors that still require study and accept that there is a significant difference between suppression of a basic transmission cycle to minimize human disease and viral eradication.

Let me deal with eradication first. It is unlikely, in the foreseeable future, that effort or consideration will be given to eradicating WEE or SLE virus from California. Both viruses are firmly entrenched throughout the Central Valley and in peripheral areas in a maintenance cycle between *C. tarsalis* and birds. Present data indicate that the threshold levels of *C. tarsalis* population that can maintain viral transmission are so low that few control districts will be able to achieve and maintain these levels in rural areas. As we progress northward into areas of water abundance, there is even less likelihood of eradication. There also is little reason to consider eradication as feasible when there are extensive areas with little or no control programs. These areas typically have a low human population density and an insufficient tax revenue base to support efficient control. The uncontrolled areas will be a continuous source from which virus can be introduced into controlled areas. The reappearance of SLE virus in Kern County in 1968 as soon as *C. tarsalis* populations increased, and after an apparent absence for 5 years, may be an example of reintroduction. Eradication of these viruses still is a conceivable goal based on current knowledge and concepts, but it is an impractical objective for immediate consideration because of economic and technical limitations.

I want to turn now to a consideration of the more practical and immediate goal to reduce *C. tarsalis* populations to levels that will prevent large numbers of persons from becoming infected and the accompanying risk that encephalitis will develop in a portion of those infected persons. The experience of the past 10 years in the San Joaquin Valley indicates that this goal was attained over a large area. Marked reduction of *C. tarsalis* populations was associated with a significant decrease in clinical cases so today encephalitis cases are sporadic and few. It must be concluded that when the viruses were restricted to their basic cycles fewer persons were bitten by *C. tarsalis* that could transmit infection. It would be expected that most of the few persons infected would not develop recognizable disease. At the same time, we must appreciate that a price is being paid both in the cost of the control effort and in that a constantly increasing portion of the population will be immune as they escape infection. No surveys of immunity have been done recently in the San Joaquin Valley but I suspect that the majority of young persons and recent immigrants into the San Joaquin Valley are now susceptible. Ten years ago a high proportion of residents were immune as a result of inapparent infections (Froeschle and Reeves, 1965). I have dwelt on this concept as it must be recognized that a breakdown in the control effort at any future date and for any reason could result in the exposure of a highly susceptible human population to a high risk of infection and disease.

I would draw your attention to the first publication that attempts to evaluate all aspects of the economic cost of an encephalitis epidemic. The publication is by Paul M. Schwab in the October issue of Public Health Reports (Schwab, 1968). His analyses of the 1966 epidemic of SLE in Dallas, Texas was based on the costs associated with care of 172 clinical cases, the control effort and the variety of associated activities. He conservatively estimated that the epidemic cost the community $796,500.00. This is a high price for a single city to pay when an epidemic resulted after SLE virus was introduced into a community of susceptible persons where there was a high population of vectors and avian hosts. If a similar economic study had been done of the epidemic of predominately WEE in California in 1952, the cost figures would have gone into millions of dollars. The magnitude of cases and areas in California was much larger than in Dallas. In addition, a higher proportion of WEE than SLE cases develop permanent residual effects. We are still paying for the 1952 epidemic in that some survivors are permanently handicapped.

I do not wish to create undue concern by my comments on increased susceptibility of populations, yet we must recognize this possibility and that the future protection of susceptible populations will depend on maintenance of the control effort.

The next area for consideration will be a variety of problems that may be unique to the Sacramento Valley area. We have known for many years that encephalitis viruses are active in this region. We also have been cognizant that this region of water surplus produces impressive and at times intolerable numbers of *C. tarsalis*, *Anopheles freeborni*, and *Aedes* mosquitoes. Historically, malaria was endemic in many communities but disappeared. We explain the disappearance of the disease largely on the basis of cultural and agricultural changes and in the low status of man in *A. freeborni* feeding preferences. Effective control of *Anopheles* was at best a marginal contributor to the disappearance of malaria. In the case of malaria, we dealt with a disease that was dependent on man to man transmission by a vector and any decrease in the probability that the mosquito would repeatedly bite man effectively stopped transmission. The encephalitis viruses are different in that man and horse are accidental hosts and are not essential to or major additives to the basic transmission cycle. We continue each year to have confirmed WEE and SLE in the Sacramento Valley; and this is not surprising, as there is a constantly increasing population of persons in areas where the viruses are active.

We are developing a research project in Butte and Glenn counties; this region is believed to be representative of the Sacramento Valley. The objective of the study will be to develop, as we did earlier in Kern County, a knowledge of the factors that influence viral transmission and the risk of human infection. We should not and cannot anticipate the findings of this research, but I will be guilty of speculation in explaining some of the earlier observations that were made in this region, as such speculation has led to some new concepts and hypotheses that may be significant.

A series of studies by staff of the State Department of Public Health revealed that *C. tarsalis* populations in the Sacramento Valley frequently were larger than in the San Joaquin Valley but this could not be correlated with higher levels of viral transmission or higher rates of clinical disease (Longshore et al., 1960). We have examined records accumulated from the proposed study area during the past summer on light trap collections, clinical cases, and the distribution of antibodies in chickens. The light trap index for female *C. tarsalis* in the Butte County district averaged almost twice that of the Kern district and the trap index for Willows averaged 10- to 50-fold higher than those from comparable sized rural communities in Kern County. In spite of these major differences in vector abundance, there were no confirmed human cases of WEE or SLE in Glenn or Butte County in 1968, although there have been cases in most summers. How can one explain these observations? First, I will comment on Willows and similar relatively small rural communities in this region. Every person in a community of this type is undoubtedly a high risk of being bitten by *C. tarsalis* and of infection with WEE and SLE viruses each summer. However, the population in the community is small, relatively stable, and, I suspect, has a very high proportion of persons with immunity to both viruses as a result of prior inapparent infection. The number of persons infected for the first time each year and who are at risk of developing encephalitis is very small. The mosquitoes carry on an immunization clinic each summer that maintains immunity in most of the persons. As for all immunization clinics, many persons believe that the bite of the mosquito or the needle is an aggravation and something to be avoided. In this instance, immunization by inapparent infection and the accumulation of immune persons in the population can actually prevent clinical disease and hide the presence of the viruses. At the same time, any susceptible transient or immigrant person who comes into or passes through the area is at high risk of becoming infected and may develop encephalitis.

The next question is, what is to be expected as new control programs are established in such areas and the established programs increase in effectiveness? All data indicate that female *C. tarsalis* are extremely mobile. A highly effective larvicidal and source reduction program that is limited to an area of several hundred square miles may result in relief from pest numbers of *C. tarsalis* but sufficient female *C. tarsalis* will infiltrate from surrounding uncontrolled areas to maintain viral transmission and a risk of human infection. Thus, we arrive at the concept that effective reduction of a *C. tarsalis* population and viral transmission may require that control be established over a region of 1,000 or more square miles to protect urban and suburban areas from significant infiltration by the vector and the viruses it carries.

Earlier I discussed the concepts of threshold levels of vector population that are necessary for significant exposure of man to risk of infection and disease and that a much lower level of vector population must be achieved to interrupt the basic transmission cycle. I want to present briefly still another concept and hypothesis that has evolved, and, if confirmed, will be important to an understanding of the impact of *C. tarsalis* control on viral transmission cycles. All of you know of situations where there is either no or minimal *C. tarsalis* control and where *C. tarsalis* is extremely abundant. We have had the opportunity to study viral transmission at localities in the San Joaquin and Sacramento valleys where light trap or bait trap indices for *C. tarsalis* were 500 or more females per night. However, we have also frequently observed that neither the mosquito infection rates nor the efficiency of transmission necessarily increased in these circumstances as we might have expected. Concurrent studies in areas with *C. tarsalis* indices in the 20 to 50 range revealed what seemed to be more effective levels of viral transmission than at the higher population levels. If this is indeed the case and it can be documented by further observation, it demands an explanation as it implies there is also a threshold level for vector population above which viral transmission in the basic cycle becomes less efficient. The practical significance of such an event would be that the establishment of a control effort in a region that had an excessive population of *C. tarsalis* that was inefficiently transmitting virus might reduce that population for a period to a level where viral transmission would be more efficient. It might take some time or an accelerated effort in the control program to reduce the vector population to a level where there was minimal risk of human infection. If the above hypothesis is true, a logical explanation would be that avian hosts that are essential to viral transmission have a tolerance level in the number of vectors they will allow to bite them before they become reactive and physically resist further attacks. Rejection of vector feeding could lead to an increased feeding by the vectors on other animals, including man, that are not suitable viral hosts, even though they may be susceptible to the disease, and thus dampen the efficiency of viral transmission. There is some evidence from studies we and others have done with birds (Dow et al., 1957) that there is a tolerance threshold of hosts to vector attack and also some evidence from blood meal studies (Tempelis et al., 1965) that an increased proportion of feedings on non-avian hosts occurs when *C. tarsalis* populations are unusually dense.

It is a most disturbing concept that there might be a phase of increased viral transmission during a period in the establishment of a control program or as a result of a program where resources would only allow a partial reduction of a large *C. tarsalis* population. However, this concept would explain dilemmas posed by earlier studies when excess *C. tarsalis* populations were not always associated with increased viral activity and continued high levels of viral transmission occurred in the presence of partially successful control. I believe this is one of the most challenging questions that we face in research on the encephalitis viruses.

I hope my comments have achieved their purpose of further orientation on evolving concepts of encephalitis prevention in California. Lest there be any question, however, I continue to believe that the only practical means for control of these diseases is to control the primary mosquito vector, *C. tarsalis.*

References Cited

California State Department of Public Health. 1968. Arthropod-borne viral encephalitis, p.1-2. In Epidemiologic Note, Bureau of Communicable Diseases, Nov. 29, 1968.

Dow, R.P., Reeves, W.C., and Bellamy, R.E. 1957. Field tests of avain host preferences of *Culex tarsalis* Coq. Amer. J. Trop. Med. & Hyg. 6:294-303.

Froeschle, J.E., and Reeves, W.C. 1965. Serologic epidemiology of western equine and St. Louis encephalitis virus infection in California: II. Analyses of inapparent infections in residents of an endemic area. Amer. J. Epidemiol. 81:44-51.

Longshore, W.A., Lennette, E.H., Peters, R.F., Loomis, E.C., and Meyers, E.G. 1960. California encephalitis surveillance program: Relationship of human morbidity and virus isolation from mosquitoes. Amer. J. Hyg. 71:389-400.

Reeves, W.C. 1968. A review of developments associated with the control of western equine and St. Louis encephalitis in California during 1967. Proc. Calif. Mosq. Control Assoc. 36: 65-70.

Schwab. M.A. 1968. Economic cost of St. Louis encephalitis epidemic in Dallas, Texas, 1968. Publ. Health Rep. 83:860-866.

Tempelis, C.H., Reeves, W.C., Bellamy, R.E., and Lofy, M.F. 1965. A three-year study of the feeding habits of *Culex tarsalis* in Kern County, California. Amer. J. Trop. Med. & Hyg. 14: 170-177.

LATEST DEVELOPMENT IN MOSQUITO AND OTHER VECTOR CONTROL RESEARCH IN THE USDA

Claude H. Schmidt

Entomology Research Division, Agr. Res. Serv., USDA, Beltsville, Maryland

I am very pleased indeed to be asked for a return engagement. Hopefully this indicates that my last presentation (Schmidt, 1968) was of interest to this group. I will cover briefly some of the highlights of the mosquito research done in our laboratories and at our field stations during 1968. The results discussed here today are research results, and many of the compounds tested are not yet cleared for use. Mention should therefore not be construed as endorsement by the USDA. As many of you are aware, much of the research of the Branch is conducted on a cooperative basis since the fastest way to get ahead is to pool talents and resources. We have been fortunate to have had the complete cooperation of mosquito control districts and of the Armed Forces, to mention just two groups. Also, in California, we have cooperated with the Bureau of Vector Control and Solid Waste Management for many years and have also undertaken several cooperative projects with persons from the universities in California and elsewhere.

Larvicides - Even though larvicides are not in the limelight to the extent they were a few years ago (they have been eclipsed by adulticides and by such sophisticated techniques as ultra low volume application), they still have a definite place in mosquito control, and some research is continuing. For example, many compounds are still receiving primary screening at the Gainesville, Florida laboratory, and those that are effective at 0.1 ppm and have an LD-50 of 50 mg/kg or higher to rats or mice go through the secondary screening to determine the dose-mortality responses. Glancey et al. (1969a) reported the results obtained with 14 promising compounds. When they tested Dursban® and Bay 78182 against 4th instar larvae of *Anopheles quadrimaculatus* Say, Dursban was about 4.5 times and Bay 78182 was about 3 times as toxic as the DDT standard (0.013 ppm) on the basis of the computed LC-90. Five of the 14 compounds had mammalian toxicities (oral LD-50 to rats) of over 1,000 mg/kg. Also, oil emulsions of ABATE® and Dursban were tested against mosquito larvae in Oregon log ponds by Lewis and Christenson (1968). The minimum effective rate of application of both materials was 0.02 lb/acre, but when the rate was increased to 0.035 lb/acre, Dursban gave 17.5 days of protection compared with only 5 with ABATE. The standard used in these tests was fenthion at 0.1 lb/acre which gave 11 days of protection.

With larvicides, it is of interest to know how much material is present in an aqueous suspension of a larvicide and also how much material larvae accumulate before they die. Bowman et al. (1969), therefore, used gas chromatography to determine the residue of ABATE in exposed larvae of *Culex pipiens quinquefasciatus* Say and the actual amounts in the test suspensions. The analytical techniques were sensitive to about 2 nanograms (a billionth of a gram) of ABATE. (It is difficult to appreciate or grasp such figures; perhaps an analogy would be useful. If you added 4 drops of vermouth to a 105,000 gal tank car of gin and mixed well, you would have roughly one nanogram of vermouth/gram of gin -- and a mighty dry martini.) When the mosquito larvae were placed in a suspension of ABATE at 0.1 ppm for 120 minutes, the residue was about 10 nanograms/larvae. As the concentration of ABATE was increased to 1 and then to 10 ppm, the amount of ABATE in the larvae increased roughly parallel to the increase in concentration. The physical behavior of ABATE in the suspension was interesting. The investigators noticed that in a 16-day test none of the ABATE in jars was lost or chemically altered; instead, the pesticide tended to settle to the bottom of the containers or to cling to the inner surfaces, quite a different finding from that observed earlier with DDT which was lost rapidly from the water surface by codistillation.

Adulticides - After promising adulticides have proved successful in laboratory evaluations, they are given preliminary field evaluation as thermal or nonthermal fogs against caged mosquitoes. If the materials still look good, they are then evaluated by making ground and aerial applications against natural populations of mosquitoes. The most recent review of adulticides was made by Lofgren et al. (1967); the research I am reporting today has been performed since their review appeared.

Glancey et al. (1969b), reported that promising results had been obtained in laboratory wind tunnel tests with 11 of 114 compounds against adult *Aedes taeniorhynchus* (Wiedemann). The most effective compound was Bay 62863, which was about 4 times as effective as the malathion standard when the LC-90 levels were compared. Also Bay 78182 was twice as effective, Dursban, Bay 77488 and Montecatini L 561 were 1¾ times as effective as malathion, and Upjohn U-24157, Upjohn U-18120, and CIBA C-9643 were about equal to the standard in effectiveness. These 11 compounds will now be field tested to determine their potential usefulness and many of them are of particular interest because they have low mammalian toxicities on the order of 1,000 mg/kg.

Also, since earlier results showed that nonthermal and thermal aerosols were equally effective, Mount et al. (1969c) compared the results obtained when 6 new insecticides were dispersed from a Curtis Model 55,000 nonthermal aerosol generator against caged *A. taeniorhynchus*. Fenthion, malathion, and naled were used as standards. Geigy GS-13005 was about equivalent to fenthion. Bay 77488, Bay 78182, and Montecatini L 561 were less effective than fenthion but equal to naled and CIBA C-9643 was much less effective than fenthion or naled but 1½ times better than malathion. Bromophos was not quite as good as malathion.

The ultra low volume[1] (ULV) spray technique looked so encouraging that two field tests were made. Lofgren et al. (1968) investigated the effectiveness of malathion and fenthion for the control of *Anopheles albimanus* Wiedemann and *Anopheles triannulatus* (Neiva and Pinto) in the Panama Canal Zone. The materials were applied by helicopter at the rate of 0.1 lb/acre of fenthion and 0.225 lb/acre of malathion, the usual recommended dose in the US, to plots of about 120 acres. At these rates, the control of anophelines in these jungles was unsatisfactory. However, when the dose was increased about threefold, good control was obtained for as long as 25-30 hours after spraying. As these investigators pointed out, "This study obviously provided only a limited approach to the problem of mosquito control in jungles and other methods besides increased dosages should be investigated. A study on the relationship between droplet size and penetration through the canopy would be of particular interest." In the second field test, Mount et al. (1969b) evaluated malathion against adult mosquitoes at Eielson Air Force Base near Fairbanks, Alaska. The insecticide was applied from the ground as an aerosol with a military thermal aerosol generator that moved at a speed of 5 miles/hour and was calibrated to deliver 40 gal of liquid/hour and from the air as an ULV aerial spray from a C-123 aircraft, equipped with 38 DZ-13 hollow-cone tips and flown at a speed of 150 mph and an altitude of 150 ft, with a resulting swath width of 500 ft. In the ground applications, malathion was 7 times more effective than DDT against caged *Culiseta alaskaensis* (Ludlow) and also gave satisfactory control of natural infestations of adult mosquitoes, predominantly *Aedes* species. The aerial application of 3.14 oz/acre technical malathion gave excellent control of adult *Aedes* species for 4 days post-treatment.

Residual Sprays - The main technique used to interrupt the cycle of transmission of malaria is residual spraying of insecticides in homes and other buildings. After candidate compounds have passed a preliminary laboratory screening test, the more promising ones are evaluated in field tests in buildings near rice fields in Arkansas and Louisiana. Of the 570 compounds tested by Gahan et al. (1967) from 1962 to 1967 at the Gainesville, Florida laboratory against *A. quadrimaculatus*, 42 produced better than 70% mortality through 4 weeks, and additional tests indicated that 5 materials with low mammalian toxicity and one with moderate toxicity were highly effective for at least 6 months when they were applied to plywood boards at the rate of 1 g/m^2. The materials, Bay 38799, Bay 77488, Bay 78182, Dursban, Neo-pynamin®, and UC-8454 were therefore compared by Gahan et al. (1968) with 2 standard materials, Bay 39007 (Baygon®) and carbaryl, as residual sprays in field tests near Stuttgart, Arkansas. These treatments were applied at the rate of 2 g/m^2. Dursban was as good as the Baygon standard and better than the carbaryl standard over the 10-12 weeks of the test; Neo-pynamin was effective only 4 weeks. The other 4 compounds produced at least 99% control during most of the test and were much better than the carbaryl standard.

As you undoubtedly know, the Department of the Army is keenly aware of the problem of malaria in overseas areas. Therefore, at the request of the Army, personnel at the Gainesville, Florida laboratory undertook tests to determine the effect of insecticidal residues on canvas tenting (Altman and Gahan, 1969). In the laboratory, wettable powders and emulsifiable concentrates of Dursban, diazinon, and Baygon were effective against adult *A. quadrimaculatus* for 24 weeks when they were exposed for 1 hour to canvas treated at a

[1]We usually limit the term ULV to application of the technical (undiluted) insecticide.

rate of 2 g/m^2. A wettable powder of Mobam® was effective for the same period; however, the emulsifiable concentrate failed between the first and fourth weeks; malathion, chlordane, and DDT were ineffective the first week. The materials were then field tested on general-purpose Army tents in the Panama Canal Zone against *A. albimanus*. When Dursban was applied at a rate of 1 g/m^2, it was effective for 5 weeks, and the other materials except DDT, were only effective 2 weeks or less. DDT was again ineffective, which was surprising. Resistance to DDT was not involved and DDT wettable powder applied to wood surfaces protected from rain and direct sunlight were effective for over 6 months so the type of surface and weathering were implicated.

Resistance to Insecticide - Malathion has been used extensively the past 8 years to control adult *A. taeniorhynchus* in Florida. In that time resistance has increased to tenfold: the dose required for 90% control increased from 0.062 in 1959 to 0.68 lb/acre in 1966 (Glancey et al., 1969c). Screening tests made to find alternative safe chemicals have therefore continued. Field tests were made in 10- to 50-acre plots in citrus groves bordering salt marshes. Materials were applied with a Stearman PT-17, owned by the Brevard Mosquito Control District, at the rate of 2-3 qt of spray/acre dispersed at 100-ft wide swaths. The results of 5 years of testing materials as emulsions and/or as solutions in fuel oil were summarized by Glancey et al. (1968). Over 89% control was obtained with fuel oil solutions of Dursban (0.025 to 0.1 lb/acre), Shell SD-8211 and Bay 41831 (0.1 lb/acre), and fenthion (0.05-0.2 lb/acre); water emulsifiable formulations of Bay 39007 (0.05 and 0.1 lb/acre) and naled (0.2 lb/acre) gave more than 94% control.

Aedes taeniorhynchus is not the only mosquito that has become resistant to malathion. When collections of *Aedes sollicitans* (Walker) made at Langley Air Force Base in 1967 and 1968 after more than 10 years of applications of malathion were brought to Gainesville, Florida, adults tested with contact spray were highly resistant to malathion, about 100 - 200 times at the LC-90 level. However, they were still susceptible to naled and fenthion (Mount et al., 1969a).

Insect Repellents and Attractants - The Branch is still vitally interested in insect repellents and is looking for more effective, longer-lasting compounds and new ways in which to use them. A screening program was established to locate and develop such repellents that would be effective at a considerable distance from their source (for want of a better term, you might call them space repellents). I reported on some preliminary screening results last year. Studies are continuing to determine the most appropriate mesh size for netting and the most effecient amount of repellent to impregnate the netting. Initial laboratory screening is done in an olfactometer with laboratory mosquitoes; then the better materials are field tested against native populations. Gouck and Moussa (1969) treated 4 mesh/inch pressed cotton bed nets with deet or M-1960 (a mixture of 30% benzol benzoate, 30% N-butylacetanilide, 30% 2-butyl-l, 3-propanediol, and 10% emulsifier) at the rate of 5 grams of deet or the mixture to one gram of the netting and tested them in Bangkok, Thailand against natural populations of *Culex pipiens quinquefasciatus* Say and *Aedes aegypti* (L.). The bed net treated with deet provided complete protection for 17 weeks against *C. p. quinquefasciatus* and for 16 weeks against *A. aegypti*; the net treated with M-1960 provided complete protection against both species for 15 weeks.

Research is also continuing on insect attractants, really the other side of the coin. If more were known about the factors that are responsible for the attraction of mosquitoes, more effective ways of keeping them off could be developed. Gouck et al. (1968) developed a new technique for screening chemicals by using *A. aegypti*: they blended low concentrations of carbon dioxide with the effluent of the test material before it was presented to the mosquitoes. Twenty-three of 104 materials tested by this technique attracted female *A. aegypti*.

Mayer and James (1969a) built another type of olfactometer that allowed them to observe behavioral responses of mosquitoes to electromagnetic radiation emanating from a host placed downwind or from a second host placed upwind. They found that carbon dioxide was apparently synergistic with arm odors in attracting female *A. aegypti*. When the subject's arm was rinsed with either water or acetone, the attractancy was reduced and the effect was particularly pronounced with acetone. In further studies of the effects of carbon dioxide and the responses of *A. aegypti* (Mayer and James, 1969b), they noticed that increasing the amount of carbon dioxide had no effect on the speed of response of the mosquitoes and concluded that carbon dioxide affected the central nervous system of the female.

Acree et al. (1968) were able to isolate and identify one of the major components of attractancy, L-lactic acid, from humans that attract female *A. aegypti*, the culmination of a 10-year search for the materials that attract mosquitoes to humans. They obtained a good correlation between the quantity of lactic acid present and the attractiveness of an individual, and they found that the effect of lactic acid depends on its form. The L-isomer was 5 times as attractive to mosquitoes as the D-isomer and was effective at very low concentrations. Ten nanograms plus carbon dioxide attracted up to 75% of caged *A. aegypti* within 3 minutes.

Sterile Male Technique - Despite some setbacks and mediocre successes with several species of mosquitoes, the search for possible uses of the sterile male technique with mosquitoes is still being vigorously pursued. In the process researchers are obtaining a greater deal of basic biological information. Darrow (1968) studied the effects of gamma irradiation on stages of *Culex tarsalis* Coquillett, and noted that when pupae were irradiated with doses of 10, 12.5, and 15 kr, the feeding of the female was reduced, but the life span of the males was not affected, and there was only a slight effect on the life span of females. Smittle (1968) investigated the effect of gamma irradiation of female *C. p.*

quinquefasciatus and found that when one-day-old pupae were exposed to 2-9 kr of gamma irradiation, the average number of eggs/raft decreased as the dose increased; at 7 kr and above, no eggs were deposited. Since only 60% sterility was obtained at 6 kr, complete sterility can apparently only be obtained by preventing egg production.

Investigators are still trying to find out whether the sterile male technique can be used successfully with *A. quadrimaculatus*. Patterson et al. (1968a) used a large caged population to study what effect the chemosterilized males would have and to provide an insight into behavior and survival in seminatural conditions. The large 40 x 16 x 12-foot cage contained a small shed where a calf was stabled to serve as a blood source for mosquitoes during the tests. Although sterile male releases were made for a 2-month period and as much as 90% of the females laid sterile eggs or sterile egg batches, control of the population was not achieved. The main reasons were poor survival and lack of competitiveness of the sterile males - probably caused by rearing conditions and excess handling. The investigators concluded that "Until a more hardy and sexually vigorous male *A. quadrimaculatus* can be reared in the laboratory, the use of the sterile male technique to control this insect seems impractical."

The possibility of using sterile males to control *C. p. quinquefasciatus* looks better. The work to date and the prognosis were summarized by Patterson and Lofgren (1969). An attempt was made to control *C. p. quinquefasciatus* in an outdoor cage by releasing males sterilized with apholate (Patterson et al., 1968b). Unfortunately, the test had to be discontinued after 9 weeks because of the advent of cold weather. However, at that time, the ratio of treated to normal males was 23:1, and 52% of the egg rafts were sterile. The lack of normal competitiveness with sterile males was probably caused by poor survival after release. Certainly, there is a real need for good, standardized mass rearing techniques that will produce hardy, competitive male mosquitoes.

Patterson et al. (1968b) reported the use of radioactive phosphorus to determine the amount and distribution of P^{32} in the reproductive system of male *C. p. quinquefasciatus* exposed as larvae to solutions containing P^{32}. They also investigated the amount of P^{32} transferred by the treated males during mating. The reproductive organs of the adult male contained about 0.86% of the total radioactivity, and about a third of this amount was in the accessory glands. During mating, about 0.09% of the male radioactivity was transferred to the females, and radioactive males were as competitive as normal males. In contrast, Smittle et al. (1969) found that the amount of P^{32} transferred by adult male *Anopheles quadrimaculatus* treated with P^{32} during the larval stages was only a little more than half that found for *C. p. quinquefasciatus*. Their laboratory males were capable of inseminating native females.

Biological Control - This year I will intentionally omit saying anything about biological control because you will have the opportunity to get the information straight from the horse's mouth, so to speak. Dr. Harold Chapman, our Investigations Leader at the Lake Charles, Louisiana laboratory, is leading a panel on this very subject at this meeting.

Control of the Tsetse Fly - Thankfully, tsetse flies (*Glossina* spp.) are not a part of the normal activities of this group and are not a problem in the United States, though they are a tremendous problem in Africa because they are vectors of trypanosomiasis (sleeping sickness) in man and of nagana, a fatal disease in cattle. The fly is present in over 4 million square miles of Africa, roughly from 10° N. latitude to a little below 28° S. latitude. Its presence is also a great obstacle to the development of the full potential of meat production. The word tsetse has an interesting origin; it was first used by some of the tribes in Bechuanaland and means "fly destructive to cattle."

Before I review some of the work we have been doing under AID sponsorship in Rhodesia, let me spend a minute or two on some aspects of the very interesting biology of the tsetse fly, using *Glossina morsitans* Westwood as an example. This fly is medium-sized, about 3/8 of an inch long, rather long lived, and the mean age of the female is about 72 days. Female tsetse flies differ from most flies in that they give birth to fully grown larvae by extruding them singly at intervals of about 10-15 days during their lifetime. The fertilized egg hatches inside the female fly and develops there through two larval stages while the larva feeds on fluid from special glands commonly referred to as milk glands. Thus, the female requires about three blood meals during each larval developmental period. When the fully developed creamy-white to pale yellow larva is deposited or extruded onto the ground, it quickly burrows into the soil where it stays to pupate, a period of 3-4 weeks or more, depending on soil temperature and soil moisture. A female, therefore, rarely lays more than 5 or 6 larvae during her lifetime, an important fact and an obstacle if one is trying to rear large numbers of tsetse flies.

Current methods of controlling the tsetse fly include insecticides, bush clearing, and game elimination, all of which are costly and vary a great deal in effectiveness. Control by sexual sterilization is another possibility, especially if it could be used as part of integrated control programs. Use of the method, of course, is dependent on the ability to rear large numbers of tsetse flies, sterilize them, and release them without affecting their vigor or behavior. The studies we have made and the prospects of control by the sterile male technique were summarized by Dame (1968a and 1968b). The investigations included research on sterility, rearing, and release of sterile males. It proved possible to sterilize adult tsetse flies either by treating them with a chemosterilant such as tepa (residual deposits or exposure in a wind tunnel) or by irradiation of the pupae or adults with doses of 8,000 – 15,000 rads and 8,000 – 12,000 rads, respectively (Dean et al., 1969). The flies were competitive in small and large field cage tests, but in the large field cage test, the treated males apparently did not compete for native females as readily as the untreated males.

During 1967, a field release program was attempted on an isolated area of about 2 square miles that had been treated with lindane to reduce the natural fly population (Dame, 1968c). Then, adult male *G. morsitans* were released after having been sterilized by contact exposure to tepa and released when they were 0-3 days old. (These adults came from field collected pupae since current rearing methods are not adequate for large scale field trials.) The released males survived poorly in the field, and the program was discontinued after 180 days without achieving control of the native population. However, in other studies made at the same time, untreated adults had a similar poor rate of survival when they were released in the field. Another field test was therefore begun in which larger numbers of sterile flies are being released to compensate for the reduced rate of survival. The evaluation of this test is not yet completed.

Control of Body Lice - Research is continuing at the Gainesville, Florida laboratory to devolop more effective powders for the control of the human body louse, *Pediculus humanus humanus* L. – the vector of louse-borne typhus. The program includes laboratory screening studies, sleeve tests with human volunteers, and finally, tests with naturally infested human volunteers. Cole et al. (1969b), reported on the results obtained from sleeve tests over a 3-year period. Powder containing 2% ABATE, 5% Mobam or 2% Geigy GS-12968 killed 100% of the lice exposed for 6 weeks.

Lice from various parts of the world have developed resistance to louse powder containing DDT or lindane, though not in the US, but as yet no resistance to malathion has been reported. Cole et al. (1969a) found that when 3 strains (one susceptible, the second resistant to DDT and the third resistant to lindane) were treated with malathion every generation for 22-44 generations, none developed any degree of resistance, but 2 showed about a 2-fold increase in tolerance. However, this does not prove that resistance to malathion could not develop in field populations exposed to selection.

Control of the Oriental Rat Flea - More efficient laboratory screening techniques for the evaluation of chemicals for the control of the oriental rat flea, *Xenopsylla cheopis* (Rothschild), were developed by Burden and Smittle (1968). The more promising toxicants were tested by exposing the fleas to dust formulations on soil; LC_{95} values were used to rate activity. Clark and Cole (1968a, 1968b) are continuing their very interesting studies on the evaluation of systemic insecticides for the control of oriental rat fleas. Four effective compounds are reported (Clark and Cole, 1968b). If effective systemic insecticides could be incorporated in rat bait, then the fleas would be killed and would not jump off the dying rodents as happens when rat baits alone are used, thus reducing the possible transmission of plague.

References Cited

Acree, F., Jr., R.B. Turner, H.K. Gouck, M. Beroza, and N. Smith. 1968. L-Lactic acid: A mosquito attractant isolated from humans. Science 161:1346-1347.

Altman, R.M. and J.B. Gahan. 1969. Effectiveness of insecticidal residues on US Army tenting against *Anopheles* spp. Mosq. News 29:415-418.

Bowman, M.C., H.R. Ford, C.S. Lofgren, and D.E. Weidhaas. 1968. Residues of ABATE®. Their analysis in mosquito larvae and larvicide suspensions by flame photometric gas chromatography. J. Econ. Entomol. 61(6):1586-1589.

Burden, G.S. and B.J. Smittle. 1968. Laboratory methods for evaluation of toxicants for the bed bug and the oriental rat flea. J. Econ. Entomol. 61(6):1565-1567.

Clark, P.H. and M.M. Cole. 1968a. Systemic insecticides for control of oriental rat fleas: Tests in guinea pigs. J. Econ. Entomol. 61(2):420-423.

1968b. Systemic insecticides for control of oriental rat fleas: Bait tests with hooded white rats. J. Econ. Entomol. 61(2): 505-508.

Cole, M.M., P.H. Clark, and D.E. Weidhaas. 1969a. Failure of laboratory colonies of body lice to develop resistance to malathion. J. Econ. Entomol. 62(3):568-570.

Cole, M.M., J.M. Hirst, J.G. McWilliams, and I.H. Gilbert. 1969b. Sleeve tests of insecticidal powders for the control of body lice. J. Econ. Entomol. 62(1):198-200.

Dame, D.A. 1968a. Chemosterilization, rearing, and ecological studies of *Glossina*. Proc. Panel, Vienna, 23-27 Jan. 1967, Organized by the Joint FAO/IAEA Div. Atomic Energy in Food and Agriculture, Control of Livestock Insect Pests by the Sterile-male Technique, pp. 23-24.

1968b. The present situation and future prospects for control of tsetse by sterile-male techniques. Proc. Panel, Vienna, 23-27 Jan. 1967, Organized by the Joint FAO/IAEA Div. Atomic Energy in Food and Agriculture, Control of Livestock Insect Pests by the Sterile-male Technique, pp. 25-29.

1968c. *Glossina* control by sterilization techniques. Proc. 8th Inter. Congr. Trop. Med. Malaria. Teheran, Sept. 1968. (in press)

Dean, G.J.W., D.A. Dame, and D.R. Birkenmeyer. 1969. Field cage evaluation of the competitiveness of male *Glossina morsitans orientalis* Vanderplank sterilized with tepa or gamma-radiation. Bull. Entomol. Res. (in press)

Darrow, D.I. 1968. The effect of gamma irradiation on reproduction and life span of the mosquito *Culex tarsalis* Coquillet. Mosq. News 28:21-24.

Gahan, J.B., H.G. Wilson, and G.C. LaBrecque. 1967. New insecticides that show residual toxicity to adults of *Anopheles quadrimaculatus*. Proc. 54th Ann. Mtg. N.J. Mosq. Exterm. Assoc., Atlantic City, March 15-17, 1967, pp. 145-152.

Gahan, J.B., H.G. Wilson, and C.N. Smith. 1968. Effectiveness of new insecticides as residual sprays for the control of *Anopheles quadrimaculatus* in buildings. Mosq. News 28:506-512.

Glancey, B.M., K.F. Baldwin, and C.S. Lofgren. 1969a. Laboratory tests of promising mosquito larvicides. Mosq. News 29:41-43.

1969b. Promising chemicals for control of adult mosquitoes. Mosquito News 29:36-38.

Glancey, B.M., C.S. Lofgren, and G.A. Mount. 1968. Aerial insecticidal sprays against resistant salt-marsh mosquitoes, *Aedes taeniorhynchus* (Wiedemann) and *Aedes sollicitans* (Walker). Mosq. News 28:593-595.

Gouck, H.K., C.E. Schreck, and D. Smith. 1968. A new technique for screening chemicals as attractants for *Aedes aegypti* (L.). Presented Amer. Mosq. Control Assoc. Mtg., New Orleans, La., March 31- April 3, 1968.

Gouck, H.K., and M.A. Moussa. 1969. Field tests with bed nets treated with repellents to prevent mosquito bites. Mosq. News (in press).

Lewis, L.F., and D.M. Christenson. 1968. ABATE, Dursban studied in Northwest project. Pest Control 36:38-40.

Lofgren, C.S., G.A. Mount, and B.M. Glancey. 1967. Update on USDA research for control of adult mosquitoes. Pest Control 9:38-43.

Lofgren, C.S., R.M. Altman, and B.M. Glancey. 1968. Control of anopheline species in the Canal Zone with ultra-low volume sprays of malathion and fenthion. Mosq. News 28:353-355.

Mayer, M.S., and J.D. James. 1969a. Attraction of *Aedes aegypti* (L.): Responses to human arms, carbon dioxide, and air currents in a new type of olfactometer. Bull. Entomol. Res. (in press).

1969b. Attraction of *Aedes aegypti* (L.): II. Velocity of host location with and without additional carbon dioxide. Entomologia Experimentalis et Applicata (in press).

Mount, G.A., C.T. Adams, and H.R. Ford. 1969a. Malathion resistance in *Aedes sollicitans* (Walker) from Langley Air Force Base, Virginia. Mosq. News (in press).

Mount, G.A., J.G. McWilliams, and C.T. Adams. 1969b. Control of adult mosquitoes in Alaska with malathion. Mosq. News 29: 84-86.

Mount, G.A., N.W. Pierce, and C.S. Lofgren. 1969c. New insecticides evaluated as nonthermal aerosols against *Aedes taeniorhynchus* (Wiedemann). Mosq. News 29:53-54.

Patterson, R.S., C.S. Lofgren, and M.D. Boston. 1968a. The sterile-male technique for control of mosquitoes: A field cage study with *Anopheles quadrimaculatus.* Florida Entomologist 51: 77-82.

1968b. Sterile males for mosquito control: A field cage study with *Culex pipiens quinquefasciatus.* Mosq. News 28:540-544.

Patterson, R.S., B.J. Smittle, and C.S. Lofgren. 1968c. Accumulation and transfer of ^{32}P by male southern house mosquitoes. J. Econ. Entomol. 61:1546-1548.

Patterson, R.S., and C.S. Lofgren. 1969. The potential use of sterile males to control *Culex pipiens quinquefasciatus* Say. Proc. 55th Ann. Mtg. N.J. Mosq. Exterm. Assoc. pp. 170-175.

Schmidt, C.H. 1968. Mosquito and related vector control research developments in the United States Department of Agriculture. Proc. Calif. Mosq. Control Assoc. 36:3-5.

Smittle, B.J. 1968. Effect of gamma irradiation of female *Culex pipiens quinquefasciatus.* Florida Entomologist 51:59-61.

Smittle, B.J., R.S. Patterson, and C.S. Lofgren. 1969. P^{32}- labeling of common malaria mosquitoes: assimilation by larvae and retention and transfer during mating. J. Econ. Entomol. 62: 851-853.

VECTOR CONTROL DEVELOPMENTS OF INTEREST TO CALIFORNIA

James V. Smith

Environmental Control Administration
U.S. Department of Health, Education and Welfare
Atlanta, Georgia

About one year ago, at the Thirty-Sixth Annual Conference of the California Mosquito Control Association, Dr. John R. Bagby, Deputy Director of the Communicable Disease Center, talked to you about the recent developments in vector control at the National Communicable Disease Center. He chose to discuss some aspects of the reorganization, or as he put it "the rebirth (of the Public Health Service) brought on by an extensive reorganization that had its beginning about 18 months ago." At that time, the realignment affected the National Communicable Disease Center (CDC) primarily by the addition of program activities. You may recall that the additions included what is now the Malaria Control Program, the Pesticides Program, and the Foreign Quarantine Program. Further realignment within CDC involved the consolidation of domestic vector control activities by the administrative addition to the *Aedes aegypti* Eradication Program of vector training, consultation, and other activities related to vectors of disease. Dr. Bagby further referred to the most recent addition to the Center in the vector control field which resulted when the decision was made late in 1967 to establish CDC as the agency responsible for the administration of the well-publicized legislation concerning the control of domestic rats in urban centers.

I have recounted these events of 1967 as relevant to my remarks this year on recent developments in vector control which may be of interest to you, for in July of 1968 the labor pains associated with the extensive reorganization (or rebirth) of the Public Health Service became greatly intensified, and eventually triplets were born. Naturally, the offspring carry some parental characteristics which show not only that they are related, but in some areas make it difficult to distinguish them.

The three offspring created are undoubtedly familiar to most of you. They are the three main organizational divisions of the Public Health Service: the National Institutes of Health (NIH), the Health Services and Mental Health Administration (NSMHA), and the Consumer Protection and Environmental Health Service (CPEHS). I do not intend to elaborate further on the realigned and newly created activities in these organizations except where it may in part give some facts related to the administrative changes in which you may have an interest.

The newly created Consumer Protection and Environmental Health Service consists of the Food and Drug Administration, the National Air Pollution Control Administration, and the Environmental Control Administration. The first two are familiar, but the Environmental Control Administration (ECA) is a new creation consisting of programs brought together from the former Center for Urban and Industrial Health, in Cincinnati, Radiological Health, and various other activities. Among these other activities is the *Aedes aegypti* Eradication Program which was transferred from the Communicable Disease Center to the

Environmental Control Administration. At the same time, the Pesticides Program was moved from CDC to the Food and Drug Administration.

During the reorganization, the DHEW made a thorough review of all its programs to insure that compliance with Public Law 90-364, the Revenue and Expenditure Control Act of 1968, would result in the least possible disruption of program activities which have an immediate and direct bearing on the public health and welfare.

To the greatest extent possible, an attempt was made to effect the required economies in such a way as to minimize the necessity of terminating completely any ongoing programs. Nevertheless, a number of important activities had to be eliminated and others had to be curtailed in varying degree. Among the latter is the program initiated in the United States in 1963 as part of a cooperative effort with other nations to eliminate the vector of yellow fever in the Western Hemisphere. This was the *Aedes aegypti* mosquito eradication program.

In view of the present budgetary situation, the decision was made to reduce the current funding so severely that all field eradication work has been eliminated, and the remaining program is being limited to research, development, and demonstration activities on new eradication techniques.

Aside from budgetary considerations, a recent review of the total program by specialists from the Pan American Health Organization and our own agency revealed that eradication of *A. aegypti* in the United States under current methodology would require major increases in annual funding levels. This was considered to be neither practicable nor of sufficiently high health priority at this time.

The redirection of emphasis on the *A. aegypti* eradication program places major support on efforts to develop more efficient or more economical techniques for eliminating the mosquito. At least four distinct areas of research are to be undertaken to implement this charge. These are ecologic studies, genetic control studies, biologic control studies, and chemical control studies. Activities in these areas will be initiated with the limited funds available.

The multiplicity of interrelationships between any organism and the environment in which it occurs provides for an unending variety of ecologic studies that can be undertaken, each of which adds to the total knowledge of the organism and any of which could provide the key to the new control technique or method being sought.

Genetic or biologic control studies will be pursued in an effort to develop nonchemical methods for reducing or eliminating selected populations without contaminating the environment with toxic materials. Genetic studies are designed to alter the chromosomal configuration in the natural population and biologic studies endeavor to locate and increase production of predator organisms or pathogenic parasites.

Chemical studies are designed to develop more efficient materials for reducing the density of selected organisms. It is also desirable to maintain a backlog of efficient materials for utilization in areas where resistance to widely used pesticides develops. Chemical studies are needed in the areas of ovicide development or in preparing materials selectively attractive to particular species, as well as the routine studies of the insecticidal potential or recommended compounds. The development of an overall integrated control system is highly desirable.

Along with the *A. aegypti* Eradication Program, responsibility for technical guidance of the urban rat control activities was transferred from CDC to the new Environmental Control Administration. As you may know, urban rat control projects are funded by grants under Section 314 (e) of the Partnership for Health Act, as amended, Public Law 89-749. At the present time, 14 of the many grant applications submitted and approved have been awarded funds totaling about 15 million dollars.

The stated mission of the Environmental Control Administration is the preservation and improvement of the physical environment to promote the health and welfare of man. This is to be accomplished through programs designed to reduce levels of exposure to the hazards of improper housing and use of space, to noise, rodent and insect vectors, occupational and community accidents, water-borne disease, radiation, and waste accumulation.

Included in the Environmental Control Administration is a Bureau of Community Environmental Management. The Bureau is made up organizationally of several divisions, one of which is the Division of Environmental Improvement. The functional statement of this Division includes the following:

> "Provides technical assistance to public, non-profit, and other public service organizations and agencies on community environmental management, community sanitation, recreation sanitation, and disease vector control. Conducts and supports research and development for the control of disease carrying insects and conducts selective control programs."

This is the Division in which the remnants of the *A. aegypti* program and the new rat control activities are now located. Within this organization plans for future activities in the area of vector control are as yet incomplete, but they presently consider a broadened scope to include arthropod and rodent control, training, consultation, and research in line with the mission of ECA. This could include a variety of arthropod and rodent problems associated with recreational areas, water developments, solid waste disposal and particularly problems associated with insanitary conditions which occur in the lower socioeconomic sections of many urban areas.

The reorganization of the Public Health Service has been accompanied by many strains and stresses. In a number of instances new bedfellows have been established and this has necessitated considerable give and take in learning to get along with one another. However, as usual, the new organization is beginning to function and we are looking ahead with real anticipation to a forward looking and forward moving program which should be expected to contribute significantly to our knowledge of vectors and vector control.

PESTICIDE REGISTRATION AS IT RELATES TO CALIFORNIA MOSQUITO CONTROL

Harry E. Spires
Inspection Services
California State Department of Agriculture, Sacramento

It is a pleasure to participate in your Annual Conference and to provide a brief review of the role of the California Department of Agriculture in the control of pesticides. Our functions are primarily regulatory in nature and the laws and regulations we administer are concerned with the registration of pesticides, the licensing and regulation of pest control operators, the control of the use of injurious materials, and the establishment and enforcement of pesticide residue tolerances.

The agricultural industry is deeply concerned and recognizes and supports the viewpoint that the primary public interest in pesticide chemicals is to safeguard the health and safety of the public. Our function is to provide this protection. We need to be assured that pesticides are used safely and effectively. This requires that our high quality food supply be free from chemical residues; that people are not injured by the application of pesticides; that our wildlife is protected from injury or destruction; and a suitable environment is maintained.

The concern of agriculture is twofold: first and paramount, is public safety and the health and welfare of the people; second, there is also a public interest which calls for the judicious and responsible use of agricultural chemicals.

The technological revolution in agriculture which has taken place in recent years has given us an abundance of high quality food at low cost. This abundance of food is essential to the high standard of living to which we are accustomed. One important factor in achieving the efficiency we have in agricultural production is the control of pests. Without pest control we would sacrifice the quantity and quality of food production which the public demands. Also, without the chemical control of pests, we would seriously harm agriculture, the state's largest industry. In California, losses from pests and the cost of controls exceed a half-billion dollars per year. Without the use of chemical controls, the loss would become substantially greater.

There is no doubt but that California farmers use more than the national average of agricultural chemicals. The same farmers realize there are hazards in the use of pesticides and consequently have strongly supported effective laws regulating their sale and use. They have found that strict enforcement of pesticide laws and regulations is mandatory if these products are to remain available to them. Their concern and ours extends to the health and welfare of our citizens through protection of food, our water supply and our fish and wildlife.

The Role of the County Agricultural Commissioner

The Department's enforcement of our pesticide laws and regulations is assisted by the work of the county agricultural commissioners. The county agricultural commissioners and their staffs, numbering approximately 700 persons, constitute the largest field force of its kind in the nation. These officials have an intimate knowledge of almost every farm in their counties and have the duty of enforcing certain pesticide controls. County agricultural commissioners, under the supervision of the California Department of Agriculture, enforce state regulations pertaining to agricultural pest control operators and the use of injurious pesticides.

Registration or Licensing of Each Pesticide Product

Each pesticide product must be registered with the California Department of Agriculture before being offered for sale in the state. This includes all insecticides, fungicides, herbicides, rodenticides, disinfectants, and similar materials used around homes and on farms for controlling pests. The cost of this work is supported by license fees paid by the registrants.

When a manufacturer desires to register a pesticide, he is required to submit extensive information, including tests he has made to establish the effectiveness of the product against the pest to be controlled. The application for registration must also show evidence that the product will leave no harmful residues. Accordingly, the manufacturer must submit information regarding acute and chronic toxicity and information concerning any hazard involved in the use of the product. Such a hazard may concern possible injury to consumers, to people applying the materials, to crops being treated, to animals, and even to honeybees on adjacent properties.

In evaluating the information, special attention is given by the Department to the need for protecting wildlife.

Where problems develop in previously approved products, the Department makes a re-evaluation. This review includes consideration of establishing a proper tolerance for any pesticide residue that remains on a crop.

When a product is to be used in other states besides California, it is the practice of the manufacturer to obtain federal registration of his product about the same time that he applies for registration in California. This practice permits a simultaneous evaluation of the product by the Pesticide Regulation Division of the U.S. Department of Agriculture and the California Department of Agriculture. If there is a need to establish a tolerance for pesticide residue on food, the U.S. Food and Drug Administration also evaluates the product. All these agencies cooperate with each other and exchange information on the product.

If a pesticide product appears to be unacceptable for registration in the state, it is refused registration after a hearing. In California, registration may also be refused on the basis that a product is of little or no value for the purpose for which it is intended, or that a product is detrimental to vegetation (except weeds), to domestic animals, or to the public health and safety, even when the product is properly used. California may also cancel registration in the case of false or misleading statements implied later by the registrant.

The California registration program, therefore, serves as a screen to eliminate worthless and dangerous materials before they are placed on the market. It further serves the very important purpose of assuring that labels of products have full directions for use and adequate warning to protect those who apply or handle them. The labeling must show the dosage and also the latest time the chemical may be used prior to harvest. These labeling instructions, if carefully followed, are designed to help prevent any illegal or harmful residue in the food crop.

Licensing of Agricultural Pest Control Operators

Before engaging in the business of applying pesticides for hire, each agricultural pest control operator is required to be licensed by the California Department of Agriculture. The agricultural pest control operator is also required to register with the county agricultural commissioner in each county in which business is done. Further, the operator must render a monthly report to the commissioner of all work done in the county.

Where a pesticide is applied by aircraft, each pilot must pass an examination to demonstrate his knowledge of the nature and the effect of the materials being applied.

If either the agricultural pest control operator or the agricultural aircraft pilot does not comply with state law and regulations, he is subject to prosecution on a misdemeanor charge or to having his license suspended or revoked.

Control of Injurious Materials

All pesticides require care in handling, and some require extensive care. In this connection, the director of agriculture, after investigation and hearing, designates those materials which, because of their high toxicity or special hazards, including drift to neighboring crops, can only be used under permit from the county agricultural commissioner.

At present, herbicides containing 2,4-D are placed in the injurious herbicide category. Other injurious materials include such arsenic compounds as calcium arsenate, sodium arsenite solution, and lead arsenate, a number of highly toxic organic phosphorus compounds, including parathion, Phosdrin®, chloropicrin, five hormone-type herbicides, 14 other pesticides, and DDT, TDE, endrin, dieldrin, heptachlor, and toxaphene, all of which require a special permit for purchase and use in California. It is also illegal to sell these materials to a person who does not possess a permit.

Testing Fruits, Vegetables, and Other Produce for Pesticide Residue

To insure there is no excessive pesticide residue on food offered for sale in the state, the California Department of Agriculture continually inspects and analyzes samples of fruits, vegetables, milk, meat, hay, and other produce in wholesale markets. Samples are also drawn from retail markets. This program of inspection and surveillance, supported by the state's general fund, has been conducted for over 30 years. It serves as a double check to be sure that state laws and regulations concerning the sale and the use of pesticides are observed.

Tolerances for pesticide residues, established under the authority of the California Agricultural Code, are the same as those established by the U.S. Food and Drug Administration under federal law.

Over a period of years we have learned that we must have a close relationship with other state agencies. Matters pertaining to registration and application of chemicals, as related to air pollution, stream pollution, treatment of water, and mosquito control, are directly involved.

It was a desire for a coordinated program of safe and effective control of mosquitoes that, in 1967, resulted in the cooperative agreement on pesticide usage between the Departments of Agriculture and Public Health, and the mosquito abatement districts.

The agreement is to provide for the protection of the public health and comfort through a coordinated program of safe, effective, and economical use of pesticides in the control of mosquitoes by qualified local government control agencies organized and operated in accordance with provisions of the California Health and Safety Code.

We believe this agreement has been of value to all of us in solving many of the problems, which we have had in prior years, and through it we can find solutions to the problems of the future.

What is most gratifying is that this cooperation is based upon a desire of all concerned and is not by legislative decree.

RECENT PROGRESS IN STUDIES WITH PATHOGENS AND PARASITES OF MOSQUITOES

Harold C. Chapman

Agr. Res. Serv., U.S. Department of Agriculture
Lake Charles, Louisiana

ABSTRACT

The status of research on Protozoa (principally Microsporidia), bacteria, fungi (Coelomomyces), nematodes, and viruses of mosquitoes was discussed. Progress was almost nil in bacteria, minimal in Protozoa, and maximal in Coelomomyces, nematodes, and viruses. The progress in nematodes was attributable to our ability to maintain cultures of them in the laboratory so as to study their life cycle and factors which influence their infectivity. The finding of several different inclusion viruses in mosquitoes has stimulated research in this group of pathogens.

FISH PREDATORS

Ernest C. Bay

Associate Entomologist, Department of Biological Control
University of California, Riverside

Dr. Leonard P. Schultz, recent curator of fishes for the Smithsonian Institution wrote with Edith M. Stern in 1948 that "nearly all the top minnows make excellent aides to public health officers and sanitary engineers, with the *Gambusia* as champion." This fish with which you are all so familiar is said by ecologist Frank Wilson (1965) to be the most widely disseminated natural enemy in the history of biological control, and is said by Dr. Louis A. Krumholtz now of the University of Kentucky to be the most widely distributed of any freshwater fish. All of this is with good cause and it is not likely that a better all-around fish than *Gambusia* is apt to be found for mosquito control. Its credentials of small size, live bearing, multivoltinism, seasonal brood repetition, temperature and salt tolerance, weed negotiation, voracity and larvivorous habit, not to mention pollution tolerance are almost too much to expect of a single fish species. This is not to suggest that local or indigenous fishes occurring in various areas should not first be considered before *Gambusia* or other exotic species are sought. Quite the contrary, and with good reason. Exotic introductions (and these include *Gambusia* where it is not native) are frequently as destructive or more so to some interests as they are beneficial to others. *Gambusia* is in fact a good example. The first known introduction of *Gambusia affinis* Baird and Girard into California was in 1922 (Lenert 1923) when a shipment was received in Sacramento and a hatchery was established in a lily pond at Sutter's Fort. *Gambusia* was rapidly spread and was immensely successful in adapting to California waters. At present the mosquito fish enjoys the distinction of being the only fish that can be moved indiscriminately about the state without a permit from the Department of Fish and Game. At the same time this fish is considered as a curse and an abomination by some of the state's leading ichthyologists. These men as members of various conservation committees are trying to suppress any further distribution of *Gambusia* in favor of "less dangerous and just as efficient larvivorous fishes." The valid concern of these men is that *Gambusia* because it is so efficient displaces or exterminates by competition many indigenous species where it is introduced. This is a problem that is not apt to be easily solved. Obviously any fish that we may yet discover that is going to be equal to *Gambusia* or surpass it in mosquito control efficiency is going to provoke the same conflicts of interest. No fish, not even *Gambusia*, limits its diet to mosquito larvae and when these are gone they will subsist on whatever similar live food is next available. Although I sympathize strongly with the fish conservationists in their quest, champions are difficult to unseat, and *Gambusia* is no exception. Early studies that were made in the southeastern and northeastern United States aimed at finding other fishes as effective as *Gambusia* for mosquito control failed (Radcliff 1915, Moore 1922). Many species are equally larvivorous to be sure, but few if any share the full array of credentials already cited for *Gambusia affinis*.

If the ichthyologists are discontent with *Gambusia* in situations where mosquito control is demanded they had best consider the more likely alternatives, further use of insecticides or habitat change and abolishment. With these prospects I think that they as we can be happy to have the mosquito fish.

With this being the picture for the mosquito fish where do we go from here? For one thing we have not put *Gambusia* to all of its tests, and fortunately where it is least studied is in those situations where it should give the fish conservationists least concern, in heavily polluted waters where other fish cannot survive, and in otherwise specialized habitats. Sharing the limelight with *Gambusia* in these studies is its sister, the guppy *Poecilia reticulatus* Peters. The guppy is native to coastal Venezuelan swamps and rivers and similar habitats in neighboring Columbia and Central America. It has many of the same credentials as *Gambusia* except that it is shy on cold tolerance. This could be an advantage in light of the preceeding discussion since *Poecilia* could be annually replaced in selected temperate mosquito breeding sites with less danger of getting out of hand and becoming a problem. Also in its favor the guppy is reputed to be more tolerant of pollution than is *Gambusia*, but this point is debatable. After a trip to Bangkok, Thailand, and Rangoon, Burma that I made for the World Health Organization in October, 1967, to study ferral populations of the guppy I was tempted to cast my vote for it as the queen of foul water. This conviction was strengthened during a stop in Hawaii where I was shown by Dr. Pat Nakagawa poultry drinking water run-off teeming with guppies where *Gambusia* that had had the chance did not make it. However, inspired by these observations we and one of my graduate students, Mr. Robert Sjogren, who is also manager-entomologist for the Northwest Mosquito Abatement District in Rubidoux, West Riverside, have been comparing *Gambusia* and *Poecilia* for pollution tolerance in local domestic sewage treatment tail-water and agricultural waste waters and we find the matter to be still unsettled. *Gambusia* as a champion as said before is hard to unseat even in this category.

In caged fish exposure studies made with *Gambusia* and *Poecilia* by Mr. Sjogren in 9 poultry waste water sites and 9 barn wash sites during the summer of 1968, *Poecilia* did come out ahead of *Gambusia* in 96-hour survival tests by a margin of 1 poultry site (6 vs. 5) and 3 barnwash sites (5 vs. 2) which is not much of an edge. The frailty of these observations has since been emphasized by the discovery of what appear to be far more pollution tolerant populations of *Gambusia* than were used in these earlier tests.

Fish that survived in the 96-hour cage holding tests were released into their respective sites and allowed to reproduce. Emphasis was on the ability of these fish to survive their new habitats rather than on their immediate ability to control mosquito larvae. In most cases releases were made too late in the season or with too few fish to expect any measurable degree of larval control to become established. However, *Poecilia* that we introduced in June into a large polluted concrete sump in Mira Loma were able to completely control *Culex* larvae by late August at which time the fish density was estimated at 200 fish per square yard. At one poultry ranch mosquito breeding site, Mr. Sjogren obtained 80% larval control in early August from a mixture of *Poecilia* and *Gambusia* that he had introduced in June. The control density in early August was approximated at only 20 fish per square yard. At another poultry ranch, Mr. Sjogren obtained only 50% control from a mixed stocking of *Gambusia* and *Poecilia.*

Finally, to conclude with the champion with which we started, Mr. Sjogren obtained complete larval control by *Gambusia affinis* introduced the preceeding autumn over the entire 1968 season in the highly polluted Norco egg ranch sump which was heavily margined with bermuda grass, and nearly 90% control in a dairy waste water sump where *Gambusia* were introduced in early June. In addition to these instances complete or near complete larval control was obtained in 10 to 12 other fresh and variously polluted breeding sources through the use of *Gambusia.*

References Cited

Lenert, Louva G. 1923. *Gambusia affinis;* its use in mosquito control. Calif. State Board of Health, Weekly Bull. 11(10):1-2.

Moore, J.P. 1922. Use of fishes for control of mosquitoes in northern fresh waters of the United States. Appendix IV to the Report of the U.S. Commissioner of Fisheries for 1922. U.S. Dept. Comm., Bur. Fisheries Document No. 923:60 pp.

Radcliff, L. 1915. Fishes destructive to the eggs and larvae of mosquitoes. U.S. Dept. Comm., Bur. Fisheries Economic Circ. 17:19 pp.

Schultz. L.P., and E.M. Stern. 1948. The Ways of Fishes. Van Nostrand. 1-264.

Wilson, F. 1965. The genetics of colonizing species. Academic Press Inc. N.Y.

PROGRESS IN BIOLOGICAL CONTROL OF MOSQUITOES – INVERTEBRATE AND VERTEBRATE PREDATORS

Robert K. Washino

Department of Entomology
University of California, Davis

The purpose of this report is to summarize some of the information pertinent to invertebrate predators of mosquitoes associated with rice fields and other semi-permanent aquatic situations in California. Results of unpublished studies reported at the 1965 annual CMCA meeting and comments on a recently completed studies on fish will also be included in this summary.

Insect Predators

Jenkins (1964) listed almost 200 insect predators of mosquito larvae, but as yet almost none of these has been considered sufficiently promising for mass rearing and release for applied mosquito control purposes. Therefore, most studies have been concerned with insects as natural control agents.

Certain inherent difficulties have hindered the study of insects as predators of mosquitoes. Feeding with piercing or sucking mouthparts and the small size of most insect predators prevent a study such as the analysis of gut contents in fish. James (1961) was able to ascertain the predation of mosquitoes by certain aquatic beetles by examining their digestive tract, but in subsequent studies resorted to tagging mosquito larvae with radioactive phosphorus (P^{32}). The use of radioactive material (Baldwin et al. 1955, James 1961) appears best for mosquito predation studies primarily on a qualitiative basis. Seriological techniques are also being used as a means for studying predation (Brooke and Proske 1946, Hall et al. 1953). However, it would seem necessary to have anti-sera with greater specificity when studying field situations containing a wide variety of closely related organisms such as are found in California rice fields.

Recent studies on potential insect predators of mosquitoes in California have included observations of their feeding behavior under controlled conditions (Lee 1967, Bay 1968) and the susceptibility of predators to mosquito larvicides (Mulla et al. 1962, Lewallen 1962, Mulla 1966). The seasonal patterns of a number of insect predators in rice fields in the Sacramento Valley were studied to determine which of these may coincide with those of the mosquitoes (Hokama and Washino 1966). Theoretically, a natural predator must remain abundant throughout the summer to be effective against both *Culex tarsalis*, which reaches its seasonal peak in early and mid-summer, and *Anopheles freeborni*, which is most abundant in late summer. Hokama and Washino (1966) found that most of the insect predators sampled reached their maximum abundance early in the summer; thereafter, they disapperaed or occurred in markedly reduced numbers. It was speculated that these might serve as effective predators of *C. tarsalis* but not *A. freeborni.* Two aquatic Hemiptera (*Belostoma flumineum* and *Corisella* sp.) attained a second peak of abundance later in the summer, thereby enhancing their utility as predators of mosquitoes (i.e., *A. freeborni*) which are ordinarily prevalent at that time.

Studies conducted during the past three years confirmed part of what was tentatively concluded after the first year. As in the earlier study, *C. tarsalis* reached its seasonal peak during early and mid-summer (between the 4th and 11th weeks after flooding). Populations of *A. freeborni* were greatest between the 11th and 19th weeks with one exception (4th week). Additional observations of the seasonal distribution of these insects as well as other considerations concerning their ability to serve as predators of mosquitoes will be discussed briefly.

Coleoptera - Maximum numbers of most of the aquatic beetles were observed during the initial 4-5 weeks after rice fields were flooded. *Tropisternus lateralis* has been one of the most widespread and consistent insects attracted to aquatic light traps in rice fields throughout much of the Sacramento Valley. It appears more tolerant of parathion than some of the other chemicals that might be used in rice fields (Lewallen 1962). *T. lateralis* and *Hydrophilus triangularis* were not as effective mosquito predators as other test insects under our aquarium conditions, but in preliminary studies recently initiated (Veneski and Washino, unpubl.), *C. tarsalis* has been found in the digestive tracts of field collected larvae of *H. tringularis.*

Peak numbers of adult *Hygrotus* were noted during the first 5 weeks after flooding and *Laccophilus* the first 8 weeks. Two species of the latter were only moderately predacious on *C. tarsalis* under aquarium conditions. Species of *Laccophilus* were reported as "active and voracious predators of mosquitoes" under laboratory conditions in Missouri (Roberts et al. 1967). Laboratory and field studies on these beetles in Canada indicated that they play a significant part in regulating the numbers of mosquitoes in rock pool situations (James 1964).

Hemiptera - At least three species of Notonectidae have been noted in California rice fields (Washino & Hokama 1968). They included *Notonecta unifasciata* Guerin, *N. undulata* Say and *Buenoa scimitra* Bare. Initially they were found in their greatest abundance early in summer, and thereafter disappeared or occurred in markedly reduced numbers. This observation could not be confirmed in subsequent years due to the low population levels. Recent studies (Lee 1967, Bay 1968) confirmed early reports (Hinman 1934) that backswimmers are highly predacious on mosquitoes. Lee (1967) reported a direct relationship between algal concentration and the number of mosquito larvae and pupae consumed. This may be an important factor in rice fields where extensive mats of algae (i.e., *Gloeotrichia*) may develop. He also reported backswimmers to be exceptionally successful in catching pupae when compared with other predators.

In spite of the ability to capture mosquito larvae under laboratory conditions, most species of water boatman (Corixidae) reportedly are not predacious on mosquitoes (Hinman 1934, Hungerford 1948). Compared with other insects tested in our laboratory, *Corisella* sp. fed less on mosquitoes than did other predators tested. When these water boatman were placed in aquarium with other insects present in rice fields, they were most consistently preyed upon by the other insects. One of the main reasons for studying this insect was that in the first year's study, its seasonal peak in early and late summer coincided with the seasonal peaks of *C. tarsalis* and *A. freeborni* in rice fields (Hokama and Washino 1966). However, more recent observations indicated that *Corisella* probably has only a single peak early in the summer. Since water boatman are the most numerous of all aquatic Hemiptera both in species and individuals in California (Usinger 1963), continuing studies on this group appear warranted.

Because *Belostoma flumineum* ranked consistently high in series of predation tests in the laboratory and had a seasonal activity pattern similar to that of mosquitoes found in rice fields, it was initially considered the most promising natural predator found in California rice fields (Hokama and Washino 1966). In subsequent observations, however, seasonal distribution differed considerably from the first year's study. Instead of peaks in the early and late summer only a single peak in the late summer was noted.

The giant water bug *(Abedus indentatus)* is a member of the same family, and was found to be an exceptionally efficient predator in the laboratory (Lee 1967).

Others - Our observations on the seasonal distribution of dragonflies and damselflies in rice fields have been limited. The immature forms can be found in great abundance during certain years and in certain rice fields, but not as consistently as some of the aquatic beetles. It is interesting to note that in the laboratory, the damselfly naiad (*Lestes congener* Hagen) was more proficient in catching the younger (I, II and III) instar mosquito larvae than the fourth stage larvae or pupae (Lee 1967).

We have tentatively concluded from these observations that no one insect remains abundant long enough during the summer season to be counted on as a natural control agent for the two species of mosquitoes associated with rice fields. However, some appeared to become sufficiently abundant probably to exert a major influence for short periods, especially during the early summer, so that they may supplement other primary control measures. Additional studies are necessary before greater reliance can be placed on insects as natural predators of mosquitoes in rice fields and similar habitats.

Vertebrate Predators

At least four species of fishes have been commonly observed in the rice fields of the Sacramento Valley. Three species (carp, bluegill, hitch) presumably enter these fields through the irrigation ditch system, and become established in the biotic community subsequently established. *Gambusia affinis*, the fourth species may also enter by this method, but more often they are introduced annually by local mosquito abatement districts. Several years ago, an unsuccessful attempt was made to introduce guppies *(Lebistes)* in rice fields. The failure of these fish to establish themselves was attributed to their inability to withstand the temperatures during the early rice growing period (J.R. Fowler, unpubl.).

In 1966, the feeding patterns of carp, hitch and *Gambusia* indicated that food availability was perhaps the major factor affecting food selection (Washino and Hokama 1967, Washino 1968). Subsequent studies (unpubl.) on *G. affinis* (1967 and 1968) appear to confirm this observation. The feeding pattern of bluegill in 1966 (unpubl.) showed considerable similarities to the patterns of the other three fish previously studied. Unlike the others, bluegill did not feed heavily on *Cladocera*, but the relative feeding pattern on chironomids and copepods was consistent with the patterns of the other fishes. The bluegill was found to have fed on *Anopheles* but not *Culex*. This fish probably belongs in a higher level than the other fishes in the trophic structure of a rice field community since it was the only fish which fed on the predacious *Belostoma* spp., hitch, *Gambusia* and other bluegills. The bluegill is probably detrimental to mosquito control because of its ability to prey on other predators of mosquitoes.

Aquatic light traps, dipping, and gut analysis of four species of fish were used to study weekly changes in the rice field fauna. By studying the habitat in this manner, it appeared that crustaceans and chironomids are the dominant organisms. Since mosquitoes appeared to occur in low density in relation to these organisms, at least in this habitat, they probably are not prime targets for predation. This is all the more reason that a successful mosquito control program cannot be considered a simple matter and necessarily will include the integration of all biological and chemical means available. Since *G. affinis* still appears to be the most dependable vertebrate predator of mosquitoes in most situations (Bay 1969), this fish in conjunction with a chemical program has been the basis for mosquito control in rice fields by many mosquito abatement districts. It is hoped that with additional studies on predator-prey relationships involving mosquitoes, both fish and insect predators may be more effectively utilized in the future and contribute considerably more to mosquito control programs in rice fields and other semi-permanent problem areas in California.

References Cited

Baldwin, W.F., H.G. James and H.E. Welch. 1955. A study of predators of mosquito larvae and pupae with a radio-active tracer. Can. Entomol. 87:350-356.

Bay, E.C. 1968. *Notonecta unifasciata* Guerin as a predator of *Culex* mosquito larvae in free and obstructed habitats. Presented at the 24th Ann. Meeting Amer. Mosq. Control Assoc.

1969. Progress in biological control of mosquitoes. 2. Fish predators. Proc. Calif. Mosq. Control Assoc. 37:15-16.

Brooke, M.M. and H.O. Proske. 1946. Precipitin test for determining natural insect predators of immature mosquitoes. J. Nat. Malariol. Soc. 5:45-56.

Hall, R.R., A.E.R. Downe, C.R. MacLellan and A.S. West. 1953. Evaluation of insect predator-prey relationships by precipitin test studies. Mosq. News 13:199-204.

Hinman, E.H. 1934. Predators of the Culicidae (mosquitoes). I. The predators of larvae and pupae, exculsive of fish. J. Trop. Med. Hyg. 37:129-134.

Hokama, Y. and R.K. Washino. 1966. Potential invertebrate predator-prey relationships in a rice field habitat. Proc. Calif. Mosq. Control Assoc. 34:59.

Hungerford, H.B. 1948. The Corixidae of the western hemisphere. Univ. Kansas Sci. Bull. 32:5-827.

James, H.G. 1961. Some predators of *Aedes stimulans* (Walk.) and *Aedes trichurus* (Dyar) in woodland pools. Can. J. Zool. 39: 533-540.

1964. Insect and other fauna associated with the rock pool mosquito *Aedes atropalpus* (Coq.) Mosquito News 24: 325-329.

Jenkins, D.W. 1964. Pathogens, parasites and predators of medically important arthropods. Bull. World Health Organ. Suppl. 30, 150 p.

Lee, F. 1967. Laboratory observations on certain mosquito larval predators. Mosq. News 27:332-338.

Lewallen, L.L. 1962. Toxicity of certain insecticides to hydrophlid larvae. Mosq. News 22:112-113.

Mulla, M.S. 1966. Toxicity of new organic insecticides to mosquito fish and some other aquatic organisms. Mosq. News 26:87-91.

Mulla, M.S., R.L. Metcalf and L.W. Issak. 1962. Some new and highly effective mosquito larvicides. Mosq. News 22:231-238.

Roberts, D.R., L.W. Smith, Jr. and W.R. Enns. 1967. Laboratory observations on predation activities of *Laccophilus* beetles on the immature stages of some dipterous pests found in Missouri oxidation lagoons. Ann. Entomol. Soc. Amer. 60:908-910.

Usinger, R.L. 1963. Aquatic Hemiptera, pp. 182-228. In R.L. Usinger (ED.) Aquatic insects of California. Univ. Calif. Press, Berkeley. 508 pp.

Washino, R.K. 1968. Predator-prey studies in relation to an integrated mosquito control program, a progress report. Proc. Calif. Mosq. Control Assoc. 36:33-34.

Washino, R.K. and Y. Hokama. 1967. Preliminary report on the feeding pattern of two species of fish in a rice field habitat. Proc. Calif. Mosq. Control Assoc. 35:84-87.

PARTIAL COMPATIBILITY AND ITS EFFECT ON ERADICATION BY THE INCOMPATIBLE MALE METHOD[1]

A. Ralph Barr

School of Public Health
University of California, Los Angeles

Laven in a recent review (1967) has clarified his concept of incompatibility in *Culex pipiens* which can be summarized as follows: Two strains are said to be incompatible if sperms of the males of one are able to induce embryogeny of the eggs of the other, but are not able to participate in that development. That is, mating takes place and fertilized eggs are laid, but the eggs fail to hatch because they remain haploid. An occasional egg produces a larva but such larvae are parthenogenetic since they do not contain genetic material from the father. Such parthenogenesis does not normally occur but is induced by incompatible sperms. Crosses between two strains may be compatible in both directions, incompatible in both directions, or compatible in one and incompatible in the other direction. Since there are many crossing types, any one strain has a set of potentialities for crossing with other strains. The crossing potentialities of a strain are thought to be constant from one generation to the next. They are inherited strictly through the female; the crossing potentialities of an individual are thought to be exactly the same as those of its mother and to have no relation to those of its father.

[1]This work was supported by U.S. Public Health Service Grant RO1-CC-00367-01, National Institutes of Health, Bethesda, Maryland 20014.

In his earliest full discussion of the subject Laven (1957) gave the results of crosses among 17 strains of *C. pipiens* from various parts of the world. Of the 289 (17^2) possible crosses among these strains, results were given, in terms of proportion of eggs which hatched, for 159. A sample of these results is shown in Table 1. Of the 159 combinations tested, the percentage hatch was above 90% in 41 cases, above 80% in 59 cases, above 70% in 72 cases, and above 40% in 76 cases (17 of the 76 were homologous crosses). These 76 crosses in which the hatching rate was 47% or higher make up 48% of the total number of crosses. They are considered to be compatible crosses even though the hatching rate was between 47% and 69% in four of the 76. The hatching rates in the 17 homologous crosses (which are not crosses at all) varied from 77 to 99%.

In the other 83 crosses, which make up 52% of the total, the hatching rate was 12% or less. Most of these crosses (66) had hatching rates of less than 1% while some (17) had hatching rates between 1 and 12%. It was thus shown that crosses could be classified into those which had a normal hatch (47% or higher) and those in which the hatch of the hybrid eggs was markedly depressed (12% or less).

Laven further showed that in crosses with a markedly depressed hatch, two results were possible, the offspring were all females or they were males and females in an approximately 1:1 ratio. The cross of Oggelshausen females and Hamburg males, for example, produced only females. When Hamburg males heterozygous for a dominant autosomal mutation (*Rap*; reduced antennae, palpi) were crossed with Oggelshausen females, none of the 50 F_1 females evidenced the mutation, which indicates that none had received the marked autosome from its father. These and other experiments indicated that in some of the crosses, all of the offspring were parthenogenetic. Laven applied the term "incompatible" to this type of cross.

Table 1. Percentage of Eggs Hatching in Crosses of Strains of *Culex pipiens* (from Laven 1957).

	MALES							
FEMALES	Hamburg	Oggelshausen	Latina	Tunis	Illinois	Tübingen	Österberg	Algeria
Hamburg	84.7	87.3	5.15	0.53	79.3	77.2	0	0
Oggelshausen	0.17	92.5	0.65	3.30	0.26	96.0	84.4	0.69
Latina	97.2	0.11	91.0	89.6	–	–	75.9	0
Tunis	97.0	0	4.05	93.1	–	95.9	0	0.15
Illinois	93.7	0.20	–	70.5	85.2	–	–	–
Tübingen	–	0	–	–	–	95.6	–	–
Österberg	0	90.1	0	1.00	–	–	76.5	85.4
Algeria	0.22	91.6	0	0	–	61.1	–	96.0

There were other crosses in which the hatching rate was suppressed, but F_1 adults of both sexes, in approximately equal numbers, were produced. When Hamburg females, for example, were crossed with Scauri or Latina males, the hatching rate was about 18% and males and females in approximately equal numbers were produced. Laven marked Hamburg females with the dominant factor noted above and found that about half of the F_1 adults evidenced the factor, as would be expected if fertilization was normal. In a further experiment Hamburg females homozygous for a recessive, sex-linked mutation (*var*; fusion of vein R_3 with R_{4+5}) were crossed with wild type Latina males. None of the F_1 adults evidenced the mutation, which indicated that its expression had been suppressed by a dominant wild type allele received from the father.

These results indicate that suppression of egg hatching may occur in crosses which are not incompatible. I propose to call such crosses "partially compatible" as I have done in a previous publication (Barr 1966). It should be noted that the only criterion Laven proposed for the differentiation of incompatible and partially compatible crosses was whether or not the offspring showed genetic material from the father; either M, the factor for maleness, or some other factor. In an extensive study of incompatibility between the Hamburg and Oggelshausen strains he showed that the overall hatching rate (mean of means) in 25 generations was about 0.3%*. In other places he says that the rate of induced parthenogenesis is about 0.1%. It is assumed that in all incompatible crosses the hatching rate is very low although the upper limit for this rate has not been established. There is reason to believe that induced parthenogenesis may occur more frequently in some strains than in others. In partially compatible crosses, on the other hand, it is not certain how low the hatching rate may be. Therefore, it is not possible to distinguish between incompatible and compatible crosses on the basis of hatching rate although it is presumed that very low hatching rates (say less than 0.5%) indicate incompatibility, while higher rates (say 0.5% or more) indicate partial compatibility. It will be noted that Laven (1966) indicates that there is no difficulty in distinguishing between incompatible and partially compatible crosses, a view that does not coincide with our own. He says: "In two cases only a single raft has been counted, but in general one single raft is sufficient for the decision whether a certain combination is compatible or not. If the first raft indicates incompatibility all further rafts will not hatch and vice verse with compatibility."

Table 2 shows the results of a typical partially compatible cross. It involves females of a strain from Stockton,

Table 2. Analysis of Egg Rafts Laid by Stockton Females Crossed with Melbourne Males.

	Undeveloped Eggs	Developed Eggs	Larvae	Total	Proportion Hatched	Adjusted Proportion Hatched
	65	8	16	89	17.9	66.7
	115	8	5	128	3.9	38.5
	38	9	13	60	21.6	59.1
	86	6	30	122	24.6	83.3
	59	6	4	69	5.8	40.0
	51	0	3	54	5.5	100.0
	101	11	8	120	6.7	42.1
	54	8	9	71	12.7	52.9
	60	15	20	95	21.1	57.1
	88	8	6	102	5.9	42.9
TOTALS	717	79	114	910	12.5	59.1
	43	12	0	55	0	0
	51	8	0	59	0	0
	31	25	0	56	0	0
	41	8	0	49	0	0
	46	5	0	51	0	0
	29	10	0	39	0	0
	53	7	0	60	0	0
	11	6	0	17	0	0
	49	2	0	51	0	0
	61	5	0	66	0	0
	132	8	0	140	0	0
TOTALS	547	96	0	643	0	0
TOTALS	1264	175	114	1553	7.3	39.4
	73	0	0	73		
TOTALS	1337	175	114	1626	7.0	39.4

California, from W.G. Iltis, and males of a strain from Melbourne, Australia, supplied by N.V. Dobrotworsky. The table gives an analysis of the hybrid egg rafts. The rafts are in three groups; the first group of 10 rafts produced larvae, the second group of 11 rafts evidenced embryonic development but no larvae hatched, the third group contains a single raft which did not evidence embryonic development and was presumably infertile.

It will be noticed that rafts of the second group are indistinguishable from incompatible rafts and if they were the only type produced the cross would appear to be an incompatible one. In incompatible crosses Laven has not reported such a high proportion of infertile eggs (85%) as are present in these rafts but in our experience this varies from one cross to another. Barr (1966) reports an incompatible ross in which the infertility rate runs about 40% as com-

* His hatching rate was calculated as eggs which hatched/eggs laid. All eggs showing no development at all (unfertilized?) were included in the denominator. It is not certain whether or not these eggs should be included. Since they made up about 29% of the total, their exclusion would raise the hatching rate to 0.4%. Frequently, such apparently unfertilized eggs constitute an even larger proportion of the total. Their inclusion or exclusion in these cases would importantly influence the results.

pared with the average 30% or so which follows from Laven's figures.

The first group of rafts, those which produced larvae, had a significantly smaller (78.8% as compared with 85.1%) proportion of undeveloped eggs than did the second group, those rafts which did not produce larvae ($chi^2 = 9.8$, 1 d.f., $p < .01$). These rafts tended to have about equal numbers of dead and hatched eggs which together accounted for about 21% of the total, the other 79% being infertile. These rafts produced a total of 114 larvae of which 100 matured to produce 48 males and 52 females. This sex ratio agrees well with the expected 1:1 distribution ($p > 0.5$).

Field Tests With Incompatibility

In preliminary testing three strains were identified which were of possible use for eradication of natural populations of *C. pipiens* in California. All of these were supplied by H. Laven. They were his Paris and Scauri strains and his marker strain for the third chromosome, which may be Oggelshausen. This latter strain will be designated "10" since the origin of its crossing type is uncertain.

The area around Hanford, Kings County, California, was chosen as a test area because of the cooperative attitude of workers of the Kings Mosquito Abatement District. *Culex pipiens* larvae were collected in the field in and around Hanford and reared to the pupal stage in the laboratory. The pupae were sexed and males put in one cage and females in another. Hanford females were crossed with Scauri males and Scauri females with Hanford males. All females were exposed to chickens for blooding although initially the Scauri strain was autogenous. Egg rafts were isolated individually in paper cups and each raft was analyzed after about 3 days, when hatching was complete. The Scauri female-Hanford male cross proved to be fully compatible so about 5 egg rafts were reared out individually to serve as Scauri crossing type parents of the next generation. This procedure was carried out for 3 generations of genome replacement, in each generation the hybrid females being backcrossed to Hanford males, and the hybrid males tested for incompatibility with females of the Hanford strain taken directly from the field.

The rafts from the Hanford female-Scauri mating-type male cross in each generation were classified as follows:

compatible . . . . normal hatch
reduced hatch . . . some larvae but many dead eggs
incompatible . . . . no hatch but with dead, embryonated eggs
infertile . . . . no embryonic development

Compatible egg rafts showed a normal hatch with few or no dead eggs. Egg rafts with a reduced hatch produced larvae but contained dead eggs in as large or larger numbers; most also contained large numbers of non-embryonated eggs. "Incompatible" rafts showed evidence of fertilization but did not produce larvae. "Infertile" rafts showed no evidence of embryonic development.

The results are shown in Table 3. When males of Scauri mating type were crossed with Hanford females in three separate experiments about 5% of the egg rafts laid hatched normally, about 38% hatched partially, about 49% did not hatch at all, and about 9% appeared to be infertile.

The 29 rafts with reduced hatch of the first generation produced a total of 32 larvae (27 rafts produced 1 larva, 1 produced 2, and 1 produced 3). These 32 larvae produced 30 adults of which 16 were male and 14 female, which is consistent with a 1:1 sex ratio. The 14 females were again crossed with Scauri mating-type males and produced 19 rafts of which 9 were classified as "incompatible" and 10 "reduced hatch." The overall hatch of these eggs was about 10% as contrasted with an estimated 1% in the preceding generation. These findings suggest that if a female is only partially incompatible with the males of another strain, her daughters will be even less incompatible; that is, the failure of a female to evidence incompatibility appears to be inherited .

The same procedure was followed in the second generation of genome replacement. Larvae from "reduced hatch" rafts gave rise to males and females in approximately equal numbers. The females, when backcrossed to Scauri mating-type males, laid 19 incompatible rafts and 7 rafts which produced 1 to 4 larvae each.

In the third generation of genome replacement there was a massive failure in the incompatibility mechanism so it was concluded that eradication of *C. pipiens* populations around

Table 3. Types of Egg Rafts Laid by Hanford Females After Exposure to Males of Scuari Mating Type.

Generation of Genome Replacement	Number Compatible	Number with Reduced Hatch	Number Incompatible	Number Infertile	Total
1	1	29	63	9	102
2	0	2	12	1	15
3	7	34	8	5	54
Total	8	65	83	15	171

Table 4. Types of Egg Rafts Laid by Hanford Females after Exposure to Males of Crossing Type 10.

Generation of Genome Replacement	Number Compatible	Number with Reduced Hatch	Number Incompatible	Number Infertile	Total
1	0	4	24	0	28
2	3	29	65	1	98
3	11	38	221	18	288
4	6	64	238	21	329
5	0	7	49	5	61
6	4	40	247	17	308
Total	24	182	844	62	1112

Hanford was not possible by using males of the Scauri strain.

Experiments With Strain 10

The same kinds of tests were done with males of strain 10. A line was set up of genome replacement; in each generation the females were backcrossed with Hanford males from the field to continue the strain, and the males were tested for incompatibility with Hanford females from the field. The results of these tests are shown in Table 4.

In six generations of testing, 2% of the rafts were compatible, 16% showed a reduced hatch, 76% were incompatible and 6% were infertile. The results are similar to those with the Scauri strain although the proportion of incompatible rafts is somewhat larger and the proportion of rafts which hatched is somewhat smaller.

Beginning in the fifth generation of genome replacement the larvae from each egg raft were reared separately. All resulting pupae were sexed and the females crossed with males of strain 10. The results of these incompatibility tests are shown in Table 5.

The rafts may be classified into several categories:

1. Large hatch, few dead eggs, both sexes produced, females compatible with 10 males; rafts $F_6$1, 59, 60.
2. Large hatch, many dead eggs, both sexes produced, females incompatible with 10 males; rafts F_5 12, F_6 305, 307.
3. Small hatch, many dead eggs, both sexes produced, females incompatible with 10 males; rafts F_6 55, 106, 117, 138, 139, 220, 261, 292, 295, 306.
4. Small hatch, many dead eggs, only females produced, incompatible with 10 males; rafts F_6 2, 35, 91, 107, 283, 284, 308.

Type 1 rafts could have arisen by contamination of the Hanford female-10 male cross with females of strain 10 or some other strain compatible with 10 males, or by the presence of Hanford females which were compatible with 10 males. The first explanation is unlikely since this kind of raft was seen so frequently and the sex of each parent was determined and confirmed before it was used in a test. It is likely that the results are due to some Hanford females' being compatible with 10 males.

Type 2 rafts could have resulted from contamination of Hanford female-10 male cross with Hanford males. This explanation is unlikely since so few rafts of this type were seen, and since the sex of each individual was confirmed before the individual was used. A contamination explanation would also not account for the large number of dead eggs.

Type 3 rafts are typical of those we have called partially incompatible. In these tests the resulting females were incompatible with males of strain 10. If this were always true, partial compatibility would not be a hindrance to eradication. Earlier tests, however, did not always give this result so the point is not yet clear.

Type 4 rafts presumably give rise only to parthenogenetic females. In these tests they could not be differentiated from type 3 rafts except that the former produced some males while the latter did not. Therefore it appears likely that some type 3 rafts were misclassified as type 4. Accurate differentiation of these two types is possible only by the use of markers.

Experiments With The Paris Strain

A single experiment was carried out with the Paris strain in the same manner as those involving the Scauri and 10 strains. The data from these tests are not strictly comparable to those of the earlier ones because they were not collected by the same workers. The results, however, were similar. Thirty-five of 138 rafts hatched (25%). Of these 7 appeared to be fully compatible and 28 hatched poorly. The other 103 egg rafts did not hatch and at least 77 of these were incompatible. Larvae from the hatching rafts produced 402 males and 498 females. The F_1 females when bred to Paris males produced rafts which hatched (in at least 5 of 11 cases); all lots which matured produced males.

Discussion

The objective of this work was to identify strains of *Culex pipiens* whose males are incompatible with females of natural populations in California. Such strains could then be used for eradication of natural populations. It is clear, however, that the males of such a strain must be incompatible with all females in the natural population. If they are incompatible only with some females in the natural population, an eradication attempt could do no more than reduce the fre-

Table 5. Egg Rafts of Hanford ♀–10 ♂ "Incompatible" Cross Which Produced Females That Were Successfully Crossed Back to 10 Males.

Raft	Eggs			Pupae		Incompatibility Test
	Infertile	Dead	Hatched	♂	♀	
$F_5$12	104	23	124	50	27	25 incompatible rafts laid
$F_6$1	7	0	132	66	51	10 compatible rafts laid
$F_6$2	7	130	5	0	5	3 incompatible rafts laid
$F_6$35	75	20	1			
$F_6$55	80	10	1			
$F_6$106	126	15	1			
$F_6$117	67	68	1	2	3	1 incompatible raft laid
$F_6$138	130	20	1			
$F_6$139	88	15	1			
$F_6$59	4	1	193	74	86	1 incompatible raft laid
$F_6$60	15	0	93	43	51	12 compatible rafts laid
$F_6$91	30	46	4	0	9	1 incompatible raft laid
$F_6$107	80	46	6			
$F_6$220	181	18	8	4	4	1 incompatible raft laid
$F_6$261	144	9	29	7	5	2 incompatible rafts laid
$F_6$283	105	60	6	0	5	1 incompatible raft laid
$F_6$284	246	11	3	0	3	1 incompatible raft laid
$F_6$292	126	27	55	4	4	2 incompatible rafts laid
$F_6$295	187	38	18	10	8	3 incompatible rafts laid
$F_6$305	34	11	109	42	56	25 incompatible rafts laid
$F_6$306	188	23	18	7	9	1 incompatible raft laid
$F_6$307	112	18	77	35	38	6 incompatible rafts laid
$F_6$308	44	118	2	0	2	1 incompatible raft laid

quency of this type of female. Any reduction in size of the population affected would be quite transitory and later releases would be even less effective.

It thus becomes important to distinguish between complete incompatibility and partial compatibility. From Laven's work it was assumed that the hatching rate would be substantially higher in a partially compatible than in an incompatible cross. A careful perusal of Laven's data, however, indicates that there is no clear differentiation of crosses into those that have very low hatching rates and those that have slightly higher ones. It now becomes apparent that the differentiation of incompatible and partially compatible crosses is very difficult unless genetic markers are used.

There has been little study of variation of crossing type within a field population thus far. Most experiments have been done on laboratory colonies which have been subjected to a certain amount of inbreeding. It is, in fact, not uncommon to initiate laboratory colonies from single egg rafts. All studies indicate that there is no variation in crossing type within the progeny of a single female. If this is true there can be no variation in crossing type in a colony which has at one time or another been continued with the progeny of a single female. The lack of variation in crossing type within laboratory colonies therefore may not accurately portray the state of natural populations.

In the experiments enumerated above it was consistently found that females from a given breeding place differed in the extent to which they were incompatible with males of a candidate strain. In all cases most of the females appeared to be completely incompatible with the test males but some demonstrated reduced compatibility and occasional females were completely compatible with the test strain. Thus far we have examined no strain whose males are incompatible with all females from the Hanford area. On the other hand we are not aware of other workers who have studied a natural population this intensively.

The relation between partial compatibility and incompatibility is not known. The mechanism of incompatibility is not understood and even less is known about partial compatibility. Both of these phenomena are characterized by the production of dead, embryonated eggs. Inbred strains of *Culex pipiens* frequently tend to accumulate egg lethals of irregular inheritance which, however, usually are not manifested in outcrosses. In partial compatibility, however, dead eggs are seen in the outcross but they are not manifested when the resultant hybrids are inbred.

We have attempted to study partial compatibility by mating white-eyed 10 females with ruby-eyed Porterville males, a cross which was previously (Barr, 1966) reported to be partially compatible. The point was that parthenogenetic eggs would have white eyes, and normally fertilized eggs would have wild-type eyes. The system turned out to have a good deal higher degree of compatibility than was previously found in this cross. Practically all dead eggs and larvae, however, had wild-type eyes, which indicates that both received genetic material from the father. The dead eggs were therefore not haploid. It was also found that occasional white-eyed eggs and larvae appeared in otherwise normal rafts. This indicates that some parthenogenesis may occur in partially compatible egg rafts.

Summary

Partial compatibility is described. The difficulty of distinguishing it from incompatibility is noted.

Three foreign strains (Scauri, 10, Paris) were tested for incompatibility with females taken directly from the field in Hanford, California. Although males of all of these were incompatible with most females from Hanford, significant numbers of females were not completely incompatible with any of these strains. It is concluded that eradication of *C. pipiens* populations from Hanford would not be possible with any of these strains.

Acknowledgments

The writer wishes to express his gratitude to H. Laven, W.G. Iltis, and N.V. Dobrotworsky for providing strains; to R.F. Frolli and other workers in the Kings Mosquito Abatement District for collection of material from the field; and to C.M. Myers, J.E. Prine, J.F. MacDonald, and T. Miura for technical assistance in the laboratory.

References Cited

Barr, A.R. 1966. Cytoplasmic incompatibility as a means of eradication of *Culex pipiens* L. Proc. Calif. Mosq. Control Assoc. 33:32-35.

Laven, H. 1957. Vererbung durch Kerngene und das Problem des ausserkaryotischen Verebung bei *Culex pipiens*. II. Ausserkaryotische Vererbung. Ztschr. Indukt. Abstamm.-u. Vererbungslehre, 88:478-5[illegible]6.

1966. Incompatibility tests in the *Culex pipiens* complex. Part 1. African strains. World Health Organization Vector control/ 66.219, 6 pp.

1967. Speciation and evolution in *Culex pipiens*. In Wright and Pal, Genetics of Insect Vectors of Disease, pp. 251-275.

CMCA INSURANCE COMMITTEE REPORT

Howard R. Greenfield

Northern Salinas Valley Mosquito Abatement District
Salinas

The subject matter for discussion before this group today is entitled "What Trustees Should Know About Insurance." This is certainly a moot question, for after I received 87 percent returns from a questionnaire sent to 60 agencies and attempted to analyze the results, I can truthfully say that to stand here today and tell you what you should know about insurance would be like telling you what you should know about women! I can't, and I hope you will forgive me for not trying. However, I can tell you what the reporting agencies are doing about providing insurance coverage for those risks they deem important.

First, let me clarify the term "insurance" so that we will all be thinking along the same general lines. Insurance is an instrument or social device whereby a group of individuals may reduce or eliminate certain risks of economic loss common to all members of the group, and this protection is obtained by equitable contributions from the members of the group. Thus, if one member suffers a loss, the cost of the loss is spread over the entire group exposed to the same hazard. Of course, there are many, many refinements to this simple explanation today, but essentially, this is the way our insurance programs are developed. I think it is important to note also that many forms of insurance routinely carried today, such as fire insurance, had their origins in the sixteenth century, and marine insurance, which some districts carry, dates back to the fifteenth century. It becomes very obvious that as our society grows in complexity, so does our insurance programs. Let me cite an example.

Thirty years ago, the Alameda County Mosquito Abatement District, under the managership of Harold Grey, instituted an advance program of insurance coverage which consisted of the following:

1. Automobile Insurance:	Cost	$261.80
2. Workmen's Compensation:	Cost	532.18
3. Fire & Extended Coverage:	Cost	76.41
Total Cost:		$870.39

Now, let us look at the programs presently in effect in the majority of districts. Although 52 districts eventually reported, I will report on only 48 districts. The others came in too late to be included in the summary.

The first four questions were warm-up questions on how the district reviewed its insurance needs, how the carriers were selected, and how active the company's agent was in the program. Seventy two percent review annually, the rest indicated the programs were reviewed as needed. Eightyseven percent indicated the agent was active in periodically reviewing the district's needs. Fifty-four percent of the districts based their contracts on negotiated costs. Thirty percent requested bids, and 9 districts had other means of selection. A little better than half of the districts (39) placed their insurance with one agent, 11 with an association of agents, and one district had two agents. Now, up to this point, the mechanics of how districts disposed of their problem has been indicated. I use the word "dispose", because most of us, when the contracts are signed, sit back with a gib sigh of relief, cross our fingers, and hope nothing happens to make it necessary to explore the fine print in the the contracts just signed.

Auto Collision

Thirty-seven percent assume or self-insure for losses caused by collision. Twenty-one percent assume responsibility for losses incurred on a named-vehicle basis and forty-five percent continue having the insurance carrier provide coverage.

Comprehensive Liability

This category presented amazing diversity of thought:

Bodily Injury Automobile:
- $50,000 to $10,000,000 each person.
- $50,000 to $10,000,000 each accident or occurrence.

Bodily Injury Except Auto:
- $50,000 to $10,000,000 each person.
- $150,000 to $10,000,000 each accident or occurrence.

Property Damage Automobile:
- $10,000 each accident.

Property Damage Except Auto:
- $100,000 to $10,000,000 each accident.

Breaking the ranges of limits into smaller units indicated a trend toward the combination of single limits into a combined single limit coverage:

- Six districts now have $1,000,000 single limit coverage.
- Two districts now have $5,000,000 single limits.
- One district has $10,000,000 combined single limit coverage.

I suspect the future will see more and more districts utilizing this method.

The issuance of "umbrella coverage", possibly more accurately described as Comprehensive Catastrophe Liability, is relatively new yet. Thirty-nine percent of the districts are now covered and 3 districts indicated they are contemplating this form of coverage.

Physical Loss of Property

Surprisingly, two districts indicated they had no fire coverage. Seventy-nine percent of the districts had extended coverage, but eight districts indicated they didn't have extended coverage. There was almost equal division between the districts (21) that had all physical loss coverage, and those that didn't (20). For theft coverage, again it was almost split. Only 54 percent of the districts reporting covered this exposure.

Equipment Floater Coverage

Thirty-four districts covered office equipment. Thirty districts covered portable equipment, but the coverage of stocks and small motors, etc. was equally split - some did - some didn't.

I was somewhat surprised to note that 6 districts provided Errors and Omission Insurance, probably better known as Malpractice Insurance.

Health Insurance

Health insurance is undoubtedly one of the more social forms of coverage provided and also one of the most rapid in growth. In 1960, for example, 28 districts had adopted some form of health insurance, with the premiums ranging from 100% (4) of the cost paid by the district, to 50% contributions by the district, to 100% employee contribution (6). At the same time, 19 districts had no plan. Eight years later, only 9 districts are without coverage. Possible, this is due to having too few employees to be able to obtain a group plan.

What are the coverages being provided?

Basic Medical	77%
Major Medical	66%
Dental	9%
Life	37%
Maternity	39%
Guaranteed Income	3 districts

I suggest that this is quite a change from just eight years ago.

Medical Examinations

Medical examinations, as a condition of employment, have been credited by some as being as equally important as insurance; and I suspect it can quite properly be called such, yet only 18 districts require a medical examination and 29 districts have no requirements.

Thirty percent of the districts indicated that they bonded some or all employees; however, 34 districts do not bond their employees.

Aircraft Coverage

For those districts which own or use aircraft in their operation, the following information will be of interest:

- 8 districts self-insure for hull damage
- 11 districts have hull damage insurance
- 7 all ground
- 3 non-taxi
- 1 full coverage

Bodily Injury Aircraft:

3 districts have	$500,000/	$1,000,000
1 district has	250,000/	1,000,000
1 district has	50,000/	1,000,000
2 districts have	300,000/	300,000
6 districts have	100,000/	300,000
2 districts have	250,000/	500,000
1 district has	250,000/	100,000
2 districts have		500,000 single limit
1 district has		100,000 single limit
1 district has no coverage		

And, finally, 17 districts indicated an interest in a herbicide contract being developed by the State Department of Public Health, and 17 districts indicated an interest (depending on what was offered) in having the CMCA provide standardized group insurance coverages.

I would like to thank Gardner C. McFarland, Chairman of the Ways and Means Committee, and William L. Rusconi for providing the following information. Mr. Rusconi was responsible for gathering information regarding damage claims paid in the past five years (other than automobile).

Out of 49 replies received, 31 districts reported no claims paid in the past five years. Sixteen districts suffered losses totaling $6,922.08. Out of 34 claims settled, the average loss was $203.50. Five claims, totaling $58,673.15, are pending.

I feel that the ratio of losses to premiums paid is very low, and it is my hope that future insurance committees will pursue the idea of possibly gaining more favorable experience ratings for mosquito abatement districts.

WHAT YOU SHOULD KNOW ABOUT WORKMEN'S COMPENSATION

P. D. Fleming

California State Compensation Insurance Fund
Santa Ana

Fifty-five years ago, the California workmen's compensation system was conceived out of the despair of the industrial revolution. That revolution was cruelly oriented to the machine and the kinds and quantities of products it could produce with an almost casual regard for the human sacrifices made in terms of industrial accidents.

The unhappy circumstances of the industrial injury was considered a necessary price on the road toward progress. Yet, the injured workman could face the consequences of an injury with almost certain knowledge that he would have to sue his employer under negligence laws hardly favorable to his cause. On the other hand, the employer faced the not too remote possibility that a sympathetic jury could seriously jeopardize the financial integrity of his business.

Enlightened and progressive thinking leaders representing management, labor and government could see no good reason in perpetuating this outmoded system and, borrowing from the experience of other pioneering jurisdictions, conceived and enacted through the legislature compulsory workmen's compensation laws. Those laws represented a marriage between management and labor. Employers gave up the right to hide behind the protective shield of the so-called common law defenses and the injured workman gave up his right to use his injury as a means of seeking personal gain and thereby financially impairing his employer.

The system, for the most part, has been intelligently used to bring both employer and employee together. In the past few years, however, a breech seems to be widening on the issue of workmen's compensation injuries as between employer and employee. Perhaps, this is being brought about by another great technological leap forward.

Industrial psychologists are warning us that automation and the accompanying computer age are insulating the employer from his employee and that both parties are looking for solutions in terms of mathematical precision. Numbers, cyphers and symbols are lending themselves to almost total impersonalization as far as out employee--employer relationship is concerned.

In workmen's compensation we are witnessing a growing tendency of employers to demand absolute proof of injury on the part of their employees before benefits are granted. On the other hand, we are seeing an increasing employee trend to pursue the workmen's compensation system for financial gain, a result not contemplated by the law.

Without regard to the human element, members of the medical and legal professions, insurance companies, and labor and management are losing sight of the fact that the workmen's compensation laws were developed as a human instrument rather than a mechanical one.

Because we are in danger of repeating the errors of the turn of the century, I think it would be wise to review what workmen's compensation purports to do, the benefits that are available and the method of funding. Lastly, an attempt must be made to reconcile the need to provide just compensation, which is sometimes very costly, with the demands made upon us all for fiscal responsibility.

The benefits of workmen's compensation were not meant to reward or fully compensate on a quid pro quo basis. Rather, they were designed to encourage injured workmen along the quickest and most direct road to rehabilitation. Injured workmen are entitled by law to all the medical care reasonably necessary to relieve the effects of an industrial injury.

Temporary disability payments are provided to tide an injured over until he can return to work and earn his regular pay. Hopefully, these payments will eliminate the necessity for the workmen to seek welfare aid or other financial assistance. Currently the maximum temporary disability benefit is $87.50. That figure in turn is based upon 65% of average weekly earnings. The minimum temporary disability payment is $25. While a great majority of our injuries involves no lost time, or at best a minimum of temporary total disability, a small percentage of claims involves permanent disability.

Permanent disability is defined as a lasting impairment of some bodily function which at least theoretically diminishes an injured's ability to compete on the open labor market. Permanent disability like temporary disability payments is based on 65% of average weekly earnings. It is subject to a maximum of $52.50 and a minumum of $20.00.

To give you an illustration of how temporary and permanent disability work, let's take the case of an injured who has lost the sight of one eye. Assuming no other complications, the man may expect to be temporarily disabled for a period of say ten weeks. If he were entitled to maximum temporary disability compensation, he would receive $875. In addition to temporary disability, he would receive a 35% disability rating for his permanent impairment. For each percentage of the rating, he is entitled to four weeks of weekly indemnity. Thus, he would receive 100 weeks of payment at a maximum of $52.50 for a total of $5,250. In terms of dollars, the injured would in this case be paid a total of $6,125.

In addition to temporary and permanent disability, the law provides death benefits for surviving dependents. In the case of a widow and child, the amount payable is $23,000. Also, a burial allowance of $1,000 is provided. For a widow alone, the death benefit is $20,000 and for surviving dependents other than widow, where only partial dependency is involved, the maximum award is $15,000.

In addition to monetary benefits, the workmen's compensation system provides rehabilitative care for those injured who because of their condition cannot return to their regular employment. This would include all expenditures necessary for retraining in a different occupation.

Life pensions are provided those whose total permanent disability exceeds 70%.

Aside from having an awareness of the benefits that are provided by the system, it is imperative that employers understand how workmen's compensation is supported. Employer's liability is usually discharged most efficiently and economically through the acquisition of a workmen's compensation insurance policy. Insurance companies by their very nature spread cost and thus minimize the effect of catastrophic injuries.

The mosquito abatement districts are insured with the State Compensation Insurance Fund. You are charged for your workmen's compensation coverage on the basis of an average rate which is derived from the cost and frequency of injuries occurring in your industry. The mosquito abatement districts are currently classified at an average rate of $4.11 per $100 payroll.

I stress the fact that this is an average rate because some of you here may be paying something less and others may be paying slightly more. An average rate does not take into consideration that individual districts may have fewer injuries costing less money, and others may have correspondingly more. As a consequence of this, and by a rating formula, some districts are entitled to credits on their average rate and others develop a penalty charge. Thus, it may be seen that the more successful you are in preventing industrial accidents, the greater the opportunity is to reduce your workmen's compensation costs.

Because workmen's compensation is considered a necessary part of doing business, the cost is ultimately passed on, in the case of private employers to their consumers; and in the case of public agencies, ultimately to the taxpayer. Thus, industry is primarily responsible for the provision of benefits and ultimately all of us share in the burden of cost.

In spite of a merit rating system, there are times when the cost of workmen's compensation seems to defy the best efforts of employers who maintain an excellent attitude on safety, provide reasonably safe work environments and good supervision.

To those employers who face this seemingly paradoxical situation there is a strong temptation to cry fraud, to suspect employees, to blame unscrupulous attorneys, a liberal industrial accident commission or poor claims adjusting. That analysis, however, will not have any affect toward reducing their cost.

I would encourage employers to adopt the following policy:

Advise your employees of their rights under workmen's compensation. It is, I believe, far better that this come from a concerned employer than someone who may be financially interested in any recovery to which an employee may be entitled. To conceal this information is unwise because employee associations, labor unions, interested attorneys, and other parties are quick to volunteer their advice.

Explain to your employees how workmen's compensation benefits are funded. Oftentimes, they are ignorant of their employer's contribution and look upon compensation recovery as simply a payment made by some impersonal insurance company.

As an employer, involve your management, supervisory and other employees in some form of accident prevention activity. This might include membership on a safety committee, involvement in the promotion of safety contests or development of an accident prevention incentive system.

Practice what you preach. If you, as trustees, your managers and their supervisors observe good accident prevention techniques your employees will tend to imitate those practices.

Take advantage of professional assistance that may be available to you. For example, the State Fund offers to its insured such safety oriented courses as first aid training and driver safety programs. Recently we have developed a rather sophisticated supervisors' course on accident prevention.

Consider the practicability of hiring the handicapped. It has been my experience that the so-called handicapped people make unusually good risks as far as future industrial accidents or attitudes are concerned.

Determine the feasibility of pre-employment and thereafter periodic health examinations for reasons of job assignment according to physical capability rather than employment termination.

Be wary of adopting an attitude that all industrial injury claims arise out of fraud. While there is little doubt there are people who will take advantage of the system the problem lies in hiring practices and personnel administration. It is extremely difficult to prove fraud and the person who engages in a fradulent proceeding against you has been stealing from you long before he recognized there may be some reward for a phony claim. A workmen's compensation appeals board is a poor place to prove that an employee is less than honest.

Lastly, use the Workmen's Compensation System as a means of improving your relations with your employees. It occurs to me that any injured employee deserves the courtesy of a personal call with the reassurance that you as an employer will do all that is necessary to facilitate an early recovery and successful return to work. This reassurance oftentimes is all that is necessary to keep the injured from seeking out costly legal redress. In those cases where a person is seriously injured, I suggest that you work closely with your State Fund claims adjuster. He is interested in the physical rehabilitation of your injured workman and shares your concern.

The claims adjuster is an expert in the procurement of the best medical care at the most reasonable cost. He has access to rehabilitation counselors. He can keep you and your injured employee informed as to the most expedient and economical solution to the injury problem.

In concluding this address I would like to re-emphasize the idea that workmen's compensation offers an excellent opportunity for the improvement of employer-employee relationships and can be used in a positive way to increase the efficiency of your operation, and reduce the cost of your business.

Perhaps then this is one way where all of us pulling together can bridge that ever widening gulf which is surely one of the menaces of our computer age.

PUBLIC LIABILITY INSURANCE

Loren J. Berry

Purchasing Department
County of Orange, Santa Ana

Our progress in life has demanded specialized study and development in all lines of endeavor. We have seen standard liability insurance of previous years segregated into specialized coverages, such as: comprehensive general liability, automobile liability, manufacturers and contractors liability, owners, landlords, and tenants liability, aircraft liability, druggists liability, and many others. Yet, due to progress and growth of civilization, each insurance coverage must continually change, expand and diversify to properly cover the insurer. So it is with comprehensive general liability insurance coverage that we in government must rely on to protect us. It is up to you and me to see to it that, even with this comprehensive coverage, conditions are set forth to cover all conditions of our operation and exposures in connection therewith.

We all recognize that in today's world we can be held accountable in the courts for our negligence, for our failure to exercise reasonable care, for our failure to act as reasonably prudent persons in the circumstances which confront us. This does not mean that we should hesitate to carry out a loss prevention program any more than a surgeon would hesitate to operate because he knows that he may be sued for malpractice if the patient feels, after a poor result, that the surgeon was careless or incompetent.

In mosquito control you face a public service that requires physical control to accomplish this public service. In this application you may be subject to being accused of negligence.

It seems in being a public servant that we are prime targets for any supposed negligence, for failure to exercise reasonable care, and any failure in operations that affects the very person or property you are, to the best of your ability, trying to save or protect.

No doubt, each one of you finds in his district different geographical conditions and types of operations that vary with each other and require different methods to be used to accomplish the handling of all conditions and circumstances to control mosquitoes.

Describing public liability is like describing a Model T Ford in order to project what our automobiles are like today.

The need for expanding public liability insurance over the past ten years has grown to keep pace with the growth and progress of our civilization.

Living with and acquiring a knowledge of claims against county government, including its districts, we find that insurance coverage standard policies are not keeping up with improved and more complicated methods of operation, due to the exposure of the population growth in California.

The comprehensive general liability insurance offered to us today should be analyzed word by word and paragraph by paragraph, to make sure that the coverage covers your operations. In purchasing this insurance, we, the buyers, may be somewhat to blame for any inadequate coverage. We must schedule the equipment used, the method of operation, and where such equipment and operations will take place. The meaning of words and paragraphs should be analyzed as to their application to your operations.

Standard policies today do not provide us with conditions to meet our present day operations.

The California Mosquito Control Association members are trying to control the same mosquito that they were confronted with ten years ago; but, is it not true that over those ten years you are continually searching for new control methods? Just as these methods and scope of control operations change, so should your insurance be reviewed for possible changes to cover such conditions. In other words, today we are being offered comprehensive liability insurance that may not be sufficiently comprehensive to cover all of our operations and exposures.

As your exposures grow, there comes a time to consider "excess" or "umbrella" amounts of coverage over practical primary limits. At this point in purchasing such insurance, be sure to provide a condition of who and at what point insurer of the primary insurance will handle lawsuits. Ask if the insurers will handle lawsuits to conclusion or only to the amount of the primary limit. This is called a "walk away" situation when counsel handles a suit to the point that the primary coverage is reached, if no excess insurance is carried. The insured may find himself holding the bag in such cases.

Buying your needs of excess insurance from the same insurer or agency usually takes care of such "walk out" counsel situations.

It is wiser to buy higher limits than low limits to save premium costs. When suits are brought against governmental bodies, the asked-for damages are always greater than against others; and regardless of "excess" additional coverage the minimum primary limits of liability coverage should be $500,000 for each person with $1,000,000 for one occurrence, with $150,000 property damage.

If your employees are deputized to make arrests, your policy should be amended to include "personal injury" to cover such exposure as false arrest, libel, slander, invasion of privacy, etc.

Review and study your accidents with those involved. If any negligence is involved, it will come to the surface and future occurrences will be minimized by these studies and exposures, whether you find them guilty of negligence or not.

I have covered some of the more important features of public liability insurance coverage, and I'm sure that you realize that books have been wirtten on this subject. Even so, I believe we learn from such meetings as this; and if this discussion has made you aware of the condition of negligence in our daily operations, we have been repaid.

EMPLOYEE BENEFITS

Robert J. Bolson, Vice President

Marsh & McLennan, Inc., Los Angeles

Medical benefits for employees are written to cover off-the-job injuries or illnesses. Compensation insurance covers on-the-job accidents. There may be some overlap, such as Group Life insurance which pays in addition to the Compensation coverage.

Group insurance had its origin about 40 or 45 years ago, following closely on the Compensation insurance field. The first benefit that was provided was Group Life insurance. It was intended as a death benefit or a burial fund for the average working man. Policies those days provided as low as $250.00 or $500.00. Rare was the policy that went to $1,000.00. Today most employers provide several times this amount, and in many cases more than the amount of an annual salary, as a death benefit.

Group insurance received its big impetus during and after World War II. Unions by law could not bargain for benefits that would contribute to inflation, such as wage increases. Benefits which were deferred were not considered inflationary, so the unions turned their attention to the field of employee benefits, such as Pensions and Group Medical plans. Since the middle forties, there has been a constant acceleration in benefits, and unions in many cases are the prime movers. When unions, particularly the large ones, such as the Teamsters or Steel Workers, bargain for employee benefits, they are doing so for many thousands of employees, plus their dependents. This has a tremendous impact on the employee benefits field, the local community, and the economy of the entire country.

A good illustration of this is found in the field of Dental insurance which, until a few years ago, was non-existent. A couple of years ago a number of unions started bargaining for Dental benefits. Today every Teamster and most retail clerks in Southern California have Dental coverage. There are two to three hundred thousand persons in Southern California now covered. This has an effect on all employers because they must keep their benefit plans competitive. Municipalities and political subdivisions must also compete in the labor market, so they must also recognize the necessity of having adequate benefit plans. Potential employees have learned to evaluate employers by the kind of benefits they provide for them.

The trend today in employee benefits is toward the so-called complete package. Not only Group Life, and Group Medical, but such ancillary items as Group Dental, Group Drug, Vision, Long Term Disability, and other items may be included.

I would like to outline for you what I would consider a minimum employee benefit plan. The term minimum is what an employer should provide as a minimum base. Many plans will provide much more than this. On the other hand, there are some which will provide less. In a Group plan you should achieve some balance between the various components. A plan that is top-heavy in Group Life and is weak in Medical benefits is poorly designed.

In my opinion, the minimum amount of Group Life insurance an employer should provide an employee would be an amount equal to his annual income. If the employee earns $5,000.00 a year, that should be the approximate amount of Life insurance provided for him. Generally, we round out the amount to the next thousand; if an employee makes $5,200.00, it would be rounded to $6,000.00.

The employee also should have an equal amount of Accidental Death coverage. In layman's terms, this is sometimes referred to as Double Indemnity; if death is accidental, instead of receiving $5,000.00, the employee's survivors receive $10,000.00.

In the field of Medical insurance, a plan should provide a reasonable hospital daily benefit. As a guide, it should be equal to about 80% of the average ward charge in the area. A ward is defined as any room with three or more beds. There is a trend in many new hospitals to eliminate the ward facility. New hospitals, therefore, have few wards, except for pediatrics; the trend is toward only one or two beds in a room. If your plan provides 80% of the average wardroom charge, you are providing a reasonable minimum benefit. The average wardroom charge in Southern California is approximately $45.00. In Los Angeles, it is closer to $50.00. Of course, you do not have to write your plan on an 80% of ward basis. You can have a dollar limit if you prefer.

In addition, your plan should pay approximately 80% of the miscellaneous charges. These are the charges the hospital assesses for the use of its equipment, for the medication it provides, and for other procedures involved in treating illness or injury.

Maternity is an event that the average employee has anywhere from seven to nine months to prepare for. It is not considered in the same serious context as breaking a leg or having cancer. Some employers do not wish to cover pregnancies, but the majority of plans do have Maternity benefits. The usual provisions for Maternity benefits are minimal – $50.00 to $100.00 – which in the average case provides not much more than one-third of the cost. You cannot pay the full cost of a maternity in the average plan involving a large female population without having a significant portion of the premium dollar allocated for this benefit.

Liberal Maternity benefits are dollar swapping with the insurance company. The people who use them are mostly under 35, and particularly the female employee who comes on the payroll for a year or two, marries, becomes pregnant, takes time off to have a baby, and in many cases does not return to work. Maternity benefits cost about a cent per dollar. Insurance is a distribution of risk, but maternity is a selection benefit that does not have the fortuitous element associated with Medical insurance.

Whether your plan should provide for doctor calls is subject to a great deal of debate. Personally, I would not recommend doctor calls in a plan. They are expensive, subject to abuse and difficult to control. I believe that the premium dollar that would be allocated for that benefit could be better spent in other areas. I do think a good benefit would be a nominal X-ray and laboratory benefit payable for such procedures outside the hospital. This could be offered on the basis of $25.00 or $50.00. It is intended to take care of the stomach pain when the individual is not seriously ill enough to be hospitalized, but could incur an expense of $15.00 or $35.00 in X-ray, etc.

Another important part of a plan, and I think that in this day and age it is mandatory in any benefit plan, is a supplementary Major Medical benefit. This takes the form of paying 80% of all charges above the Basic benefits as well as expenses not covered under the Basic plan, up to a usual maximum of $5,000.00 to $10,000.00. This would be a very simple illustration of Major Medical. Assume that an employee had expenses of $1,100.00, and your base plan pays $400.00. That gives him an excess balance of $700.00. He would pay $100.00 of that himself, and the Major Medical benefit would pay the remaining $600.00. With a minimum Basic and Major Medical plan like this, there will be few cases of an employee, or a dependent, who will have high out-of-pocket expenses unless they become involved with an organ transplant.

It is always possible that an employee might have cancer, etc., and incur expenses of $25,000.00 to $50,000.00, so the trend today is for Major Medical plans to provide maximum benefits in this range. The rental on a diuralysis machine for an employee with a kidney infection for a fairly short period could easily reach $10,000.00. We must look to the future – organ transplants are becoming more and more frequent – and they will not become inexpensive.

I would estimate that within the next several years the Health plan trend will be to provide $25,000.00 or $50,000.00 maximum benefits owing to the rising cost of medical attention. These comments are not made to criticize anyone in the medical profession for what he charges. It is a matter of economic fact that good medical care and treatment are expensive. Either the insurance industry and the employers will meet these costs, or the Government will step in and fill the void.

Now, what does the average minimum Basic and Major Medical plan cost? It varies considerably, depending on age, sex, makeup of group, size, and prior claims experience. As a rule of thumb, approximately $7.00 to $10.00 a month for the employee and an additional $14.00 to $20.00 for dependents. My costs are somewhat on the high side. Many of you from small areas don't pay that much now, but I am giving you the average cost throughout the State.

The trend in benefits is far beyond the original concept of Life insurance, Hospital, Surgical, and Major Medical plans. Today many plans are incorporating Dental benefits. A Dental plan can be written in any number of ways, but the most common one pays 80% of a schedule. A schedule might run as low as $20.00 for an extraction, and up to $300.00 for an upper and lower denture. The claimant usually receives 80% of the amount. Some plans have deductibles, others do not. The average Teamster plan, which is the type I previously mentioned, costs about $10.00 to $12.00 a month for a family. That is quite expensive, though not in relation to the benefit. It is only expensive in relation to what you as employers have to pay for the benefits you want to provide. When you consider the cost of a

Life and Medical plan, add your Pension plan costs, if you have one, and other fringe benefits, an additional $10.00 or $12.00 for Dental coverage is an expense that I would suggest an employer consider only after he has taken care of other more important areas. Certainly, I would never reccommend that an employer put in a Dental plan in preference to a Pension plan. A Pension plan may cost a lot more, but is far more socially and economically desirable than Dental coverages.

Vision Care is another benefit plan which is becoming quite popular. This is one about which the insurance business itself is not enthusiastic because it really becomes a dollar-swapping arrangement. The average cost of a pair of glasses, including refraction, lens, and frame, is about $50.00 in California. The average Vision Care plan costs from $2.50 to $3.00 a month for one family. Is this an insurable item? It is if you want it to be, but is it not like insuring the tires on your automobile? The insurance companies will sell it, but for practical purposes they are not pushing it. The impetus for it is coming from the unions.

Drug plans are in the same category. Many plans will pay 80% of the cost of drugs. The average prescription in this State, according to the California Pharmaceutical Association, is about $4.55 or $5.00. That means you are insuring $3.50 to $4.00 on a prescription. Is this insurance, and is it desirable? I leave it up to you to decide.

We are quite concerned with the Long Term Disability benefits because we believe this is good insurance. Long Term Disability is a plan which provides between 40% and 60% of an individual's income after he has been disabled for a reasonably long period of time – generally three to six months. Because the California UCD law pays up to six months for disability, most Long Term Disability plans in California have a 181-day waiting period. Normally, benefits under Long Term Disability are integrated with Social Security Disability. Social Security Disability benefits, as you are aware, provide a minimum subsistence level. Long Term Disability plans are intended to supplement that level and provide the individual a reasonable income during his disability period. This kind of benefit is good, and is socially and economically desirable. Otherwise, disabled employees would, in many cases, become public charges. What does the average Long Term Disability plan cost? As a working figure, from ½ to 1% of the employee's annual income. If he makes $1,000.00 a month and it is a ½% rate, it would cost the employer $5.00 a month. Most employers find that it is not practical to contribute to Long Term Disability plans because of the way in which our revenue code is set up. If the employer makes a contribution which is too high, the benefit is a taxable income to the employee. If the employee buys it all, it is not subject to any income tax.

I notice that about nine of your districts have no coverage. In most cases these are small groups – perhaps three or four employees. In California, as in most states, the state code provides that you must have ten full-time employees before you can secure true Group insurance. True Group insurance means that the insurance carrier provides the benefits without any requirement that the individual disclose anything concerning his medical condition, or his medical history. If an insurance company accepts a true group, it must accept every member. For groups of less than 10 members – 4 to 9 – most companies, including Blue Cross and Blue Shield, do offer what is called franchise, wholesale or quasi group. This is not true Group insurance. Here, the individual completes a medical questionnaire and the carrier has the right to waiver his condition, accept him, or reject him. Sometimes if five persons are eligible and two are substandard risks, the carrier may refuse to take the whole group, because it does not want to take these two substandard risks. For those of you with three or less employees, there is no solution under existing arrangements. You cannot get quasi group or true group. Your only alternative would be to go to some insurance company and try to get individual policies for each of the two or three persons on your payroll. This is not the most desirable approach, because the benefits are restricted, the cost is high, and people can be turned down. But even that type of benefit may be better than none.

For those of you who have persons over 65 on your payroll, I don't think you need be concerned. Medicare does do a fairly adequate job for those individuals who qualify for it, which is practically everyone receiving social security.

Whether or not it would be practicable for you as districts to combine together for purposes of securing Group insurance, is questionable. I do not necessarily recommend it to you, but I throw it out for your own thinking. Normally, we find that we have to have a couple of hundred persons, before we can set up a worthwhile, practical, good Group insurance program. Some associations have found that by pooling their interests, which is permissible under the state code, they can improve their benefit and situation. But the path is long and thorny. Those of you who can do better cost and benefit wise outside of an assocaition plan won't be too interested. Unless you can secure unanimous cooperation in an association Group plan as to all entities working together for the common interests of each other, the objective of a plan for the members will not be achieved.

AIRCRAFT LIABILITY INSURANCE

Roy Hester

Agricultural Aircraft Association
San Jose

In our work with the commercial aerial applicators we have learned a great deal about their mission, their problems, and their techniques. We have developed a reasonably good insurance program over a period of more than 20 years, which has offered adequate protection at premium levels which compare with the insurance costs of commercial operators in other phases of aviation, such as aircraft sales, training, rental and charter.

In this development the insurance underwriters have enjoyed a number of advantages in the exclusions and restrictions imposed in their policies, as well as in regulations imposed upon the operators by federal, state and local agencies.

As the operators have introduced more voluntary controls, and as they have accepted more legislative restrictions, their insurance policies have grown broader, less restrictive and more economical.

All this mind you has taken place in an industry whose objective is to make money, and whose mission is to serve its private clientele.

The similarity between your operations and those of the commercial applicator are easily drawn: both are engaged in dispensing economic poisons by aircraft.

There the similarity ends.

Where the commercial operator may work under controls imposed by his own judgment, and under restrictions imposed by various agencies having jurisdiction over his operations, as well as over the operations of his client, the mosquito abatement district must operate more in the atmosphere of expediency, like the fire protection district, police department and other safety agencies supported by and operating under the mandate of the public which they serve.

The commercial applicator has a contractual obligation to a single client and must show performance to that client if he expects to get paid. He must confine his application to the property of that single client or suffer dire consequenses -- often involving his insurance carrier in these consequences.

The mosquito abatement district owes an obligation of performance to the entire community and must be free of restrictions beyond its own integrity if it is to satisfy its obligation -- to destroy mosquitoes wherever they may be found.

Obviously, it is in the differences rather than the similarities between the respective operations that the insurance underwriters are interested.

Aviation insurance still is a relatively new field of insurance. It is subject to what we call "judgment underwriting" rather than actuarial or statistical rating procedures. It is of course highly specialized. Likewise, providing insurance for political subdivisions, states, cities, school districts, and fire districts requires specialized underwriting knowledge. Put them together, and you present the insurance market with a highly experimental underwriting program.

In looking through the material offered me in the preparation of this discussion, I noted that those districts operating their own aircraft generally obtained insurance policies from markets which are familiar to the commercial applicators and probably offering identical contracts of insurance.

I certainly have no reason to question these policies, except that most of them were developed through direct negotiations between the commercial and agricultural aircraft industry and the underwriters producing the policies. Probably the policy provisions and rates are identical with those of the commercial operators, including exclusions, loadings for chemical classifications and territories, and requirements for compliance with federal, state and local regulations relating to agricultural aircraft operations.

The time may well be appropriate for the California Mosquito Control Association to combine its efforts toward the collective negotiation for its aircraft insurance requirements, much as the commercial applicators have done.

Of the 60 mosquito control districts in California, 20 of them now own and operate their own aircraft. Some twelve others maintain contracts with the commercial applicators for aerial application. These combined operations in 1967 treated nearly two million acres in the control of mosquitoes, over twenty percent as much acreage as that treated with pesticides by the commercial aerial applicators in California.

The present level of aircraft involvement in your activities, and the fact that aircraft insurance is of sufficient interest to rate an important spot at this Conference, indicates to me that expansion of aerial application into the mosquito control industry will be rapid.

Anticipating this expansion, I suggest that it would be a worthwhile project for your insurance committee to make a thorough survey of your insurance requirements and of their relationships to existing insurance markets and contracts of insurance available.

Because of the diversity of their operations and individual insurance requirements, we have never been able to arrange a successful group liability insurance program for the commercial operators. This of course does not apply to their workmen's compensation program which has been an unqualified success for nearly fifteen years.

However, the very factors which might prohibit a group program in private industry appear to be quite favorable to the California Mosquito Control Association:

1. Operating methods are quite similar between the various units of the industry.
2. Exposure factors presented to the insurance underwriters are similar, if not identical. For example, we can assume that liability limits might be identical for each district throughout the association, and also that chemical formulations used by the various districts would fall into a single class.

3. The basis of premium can be applied uniformly to the districts within the Association, and to the operating units within each district.

Identified a little differently, these factors are what make it possible for the insurance carriers to successfully underwrite group programs in workmen's compensation, health and accident and other forms of insurance, whereby an attractive volume of premiums is offered to the insurance carrier and extra benefits are made available to the group in broader coverages, more just and economical rates, and in many cases participation in the carriers profits in the form of dividends.

We citizens are grateful to the California Mosquito Control Association for its activities in behalf of our health and comfort. We are impressed by the magnitude of your efforts, especially in the adaptation of the aircraft to mosquito control operations. As a member of the insurance profession I feel that you are entitled to recognition by the aviation insurance market as an entity apart from other general aviation classes.

THE STATE DEPARTMENT OF PUBLIC HEALTH ITS ROLE AND RESPONSIBILITIES IN VECTOR CONTROL AND RELATED ACTIVITIES

Richard F. Peters

Bureau of Vector Control and Solid Waste Management
California Department of Public Health, Berkeley

I debated very strongly with myself when you invited me to address the California Trustees, with whom I have talked person to person over the years, as to whether you needed to know more about the Bureau of Vector Control and its program in the Department of Public Health and where the Bureau relates to the whole scheme of things. Then I reflected a bit and realized that inside of the last year I also have had difficulty in keeping things straight, let alone pronouncing some of the new designations that have come into existence within my very own program. So, I decided that perhaps I should recite what recent changes have happened.

Early last year I was working for the Health and Welfare Agency. I worked then, as now, in the Department of Public Health, but I worked for the Division of Environmental Sanitation as Chief of the Bureau of Vector Control. Since December 1, I have been employed by the Human Relations Agency in the California Department of Public Health, but in the Division of Environmental Health and Consumer Protection and the unit of which I'm still Chief is now the Bureau of Vector Control and Solid Waste Management. All of this has happened in this recent period of time, perhaps also conveying the inference that I've got something to worry about besides mosquitoes. I assure you this is very much the case.

I remember, in 1935 when I attended the University of California, coming to the first class in paleontology and noting Professor Chaney stumble as he caught his heel on a new carpet laid on the floor of the speakers' rostrum in Wheeler Auditorium. He said "Well, blast that development; that wasn't here when I lectured last year." He then went on to point out that change is constantly under way, both for good and otherwise. Referencing this very thought to the origin of the California Department of Public Health is a most interesting story which I would like to relate, because it does show pretty much how we have come to be what we are today, not as a result of careful planning, but by capitalizing upon crises. This is a regrettable statement to have to make, but most of our gains in public health occur because some event happens which calls to the attention of the legislative and the executive branches of government what should have been done previously to prevent it happening. Then monies become immediately available.

California has the distinction of having had the second Board of Health within our nation, even though we are a relatively young state. Our Board of Health was organized in the year of 1870, second only to Massachusetts. The reason a Board of Health was organized was that following the gold rush days the intestinal diseases and a variety of other diseases were rampant. Cholera and typhoid fever were problems of great importance, and alas, malaria was also of such great importance that something urgent had to be done. It took people with perspective to start things happening and they arranged by strong representation to our legislature to get minimal funds to utilize the meager knowledge then available. We have to remember also that in this period disease wasn't known to be caused by microbes, but was represented to be caused by "miasmas," foul air and all sorts of other mysterious influences. Infection in today's sense of the word wasn't even understood.

A man by the name of Thomas Logan worked for twenty years in order to get our Board of Health established. He was its founder and became its first executive officer. The whole concept of state responsibility then was linked to disease reporting and the arresting of disease as best it could be done. Thus, the whole purpose of the Board of Health was to act as a central agency for reporting of disease and the quarantining of disease. Quarantining was a strong word in those days. Any time that a disease epidemic broke out quarantining was the practice and everybody was confined until all the people involved either expired or got better. The latter were then released from quarantine.

Shortly after the turn of the century that ominous thing called "black death" – plague – appeared in the coastal cities of California. These episodes of rat-borne plague, which presumably originated by way of the ships that docked in San Francisco and Los Angeles harbors and ultimately in Oakland, became a matter of great concern in California.

The State Department of Public Health began to obtain its foundations when plague became more important, and when the California climate became better appreciated for its therapy upon tuberculosis and many people with so called "consumption" flocked to California. These diseases, and of course the social diseases - they weren't even called venereal diseases in those days - became objects of the department's early attention. It was individual physicians who had a strong desire to help prevent and control these communicable diseases who gave rise to the early departmental activities. Thus, in the early years of this century, the department began to shape up as something separate and apart from a Board of Health, which then performed most of the official actions through its executive secretary. The executive secretary of the Board became the Department Director as the staff increased, but it didn't increase drastically; it increased in small stages. A laboratory was found to be essential in order to confirm that illnesses were indeed caused by infections, so a state hygenic laboratory was created to aid the department in fulfilling its preventive activities in relation to communicable diseases. Interestingly enough, early in the first decade of the twentieth century the biggest name in California Mosquito Control - Professor William B. Herms - emerged as the University of California's contribution to the prevention of malaria. Professor Herms, having heard of the outbreaks of malaria in California (from 1891 to 1896 California had twelve thousand cases of malaria) came to the University of California in 1908. Shortly afterwards he was made a consultant to our department. It wasn't too much later that another very prominent name - Harold Farnsworth Gray - came into view in conjunction with Professor Herms. Both were later to be associated with the Alameda County Mosquito Abatement District and both formed the one-two punch of the early efforts directed against malaria in California. The two of them in collaboration with the railroads, and in those days the railroads were a very important force in demonstrating new concepts of disease prevention and control, went on a crusade to Penryn and Oroville. In fact, Harold Gray met his wife Harriet during the demonstration project in Oroville. This team actually pioneered the control of *Anopheles* mosquitoes in those early demonstration and educational activities. They were really taking the message to the people way back when. Also, the name Harold Gray appears in the background of the Department of Public Health, for he was a district health officer from 1917 to 1919 covering the Sacramento Valley region. The state was broken down into five regions for a brief period of time.

The next episode relating primarily to malaria came through support of the Rockefeller Foundation in the early 1920's. It provided an engineer by the name of Lennert and subsequently a man by the name of Stewart through the International Health Bureau in collaboration with the United States Public Health Service. These engineers performed control demonstrations in the Sacramento Valley.

In 1915 the Mosquito Abatement District Act was passed by the legislature. Professor Herms had tried to accomplish this for a number of years previously on the basis of malaria control. In those days that only rang a small bell, but when the real estate lobbyists said, "we can't develop the peninsula area, the San Mateo and Marin County areas, because the mosquitoes torment our clients", this was the real thing that impressed the legislature - the almighty dollar! This lobby and that which Professor Herms was carrying almost alone on the need for malaria control persuaded the legislature to pass the Mosquito Abatement District Act.

Those engineers who came to California in the early 1920's also did something unique. You've all heard a lot about the mosquito fish, *Gambusia affinis*, which today has been revered and vilified, depending upon whether you are getting good results from it or not. Well, these engineers arranged for the importation of that fish into California in the year 1922 from two localities in Texas and the first arrival of 600 fish was planted in a Sutters Fort lily pond. They were distributed that year up and down the Sacramento Valley and to other parts of the State (without permission of the State Fish and Game Commission which really created some Hell, if you know what I mean ...).

In 1930 the California Mosquito Control Association was organized by the big two, Professor Herms and Harold Gray. Harold Gray was then the first manager-engineer of the newly formed Alameda County MAD, which was about fifteen years late in getting organized.

In 1931 came the SERA program. I don't know how many of you are aware of the SERA program, but it became the California counterpart of the depression WPA program. During this particular period there was a substantial public works program which utilized the various California MADs for work projects. There weren't very many districts then and they were very small, but they employed a lot of people to do permanent work in mosquito control.

Then came 1938 and the research of Dr. K.F. Meyer. Dr. Meyer distinguished between polio and encephalitis and suggested that mosquitoes were the transmission agents for the virus infection that was not polio, but was encephalitis. Also, 1938 is the year of our first knowledge of *Aedes nigromaculis* having obtained its beginnings in California, from which it has become a curse almost statewide. And then appeared another interesting name. Senator Breed may be surprised to hear this, but in 1939 none but Sid Dommes became the first full time employee of the California Department of Public Health to be assigned to mosquito control. He's now President of the Alameda County MAD Board of Trustees and he's also a supervising sanitary engineer in our Department's Bureau of Sanitary Engineering.

Then came Yours Truly into the scene. After I had spent a little time in local public health work, I became the state mosquito control officer, having succeeded Sid Dommes. In this pre-war period, I helped step up the WPA program which became the forerunner to the Mosquito Control in War Areas program. In this regard, I was subsequently rewarded after being commissioned into the Army of the United States. Although I had been a mosquito control officer for the State of California, and had made mosquito and malaria surveys throughout the entire state, when I got to Camp Beale -- whom did they appoint as Mess Officer? It was a very trying experience because I actually could have done Camp Beale some good in this particular respect, but the army didn't operate that way. Later, however, I was sent to the far reaches of Asia and there had a chance to make up for this misgiving.

During that period of World War II, a lot was taking place in irrigation expansion in California and the mosquito problem was in general getting real bad. Also, in the year 1944, the American Mosquito Control Association was organized. So you see all these developments are very recent in terms of time.

Upon my return I found an aroused mosquito control interest. A report had been written on the disease bearing hazard of mosquitoes in California, since the public and the legislature were concerned about all the returnees from every far reach of the world, and the possibility that mosquito-borne diseases could readily be introduced into the state. The legislature decided the best way to tackle this matter was by way of the local mosquito control agencies. These were benefitted with a subvention program in the year 1946, administered by the California Department of Public Health. At that time we didn't even have a Bureau of Vector Control; there was a mosquito control section created that year in the Division of Environmental Sanitation. We gradually acquired staff numbering about a half dozen. Arve Dahl, whom some of you remember, an engineer from the Public Health Service who had been working in mosquito control in war areas program, was put in charge of that program. The Bureau of Sanitary Inspections, which had charge of the plague survey activities in the state, as well as miscellaneous public nuisance control activities, was amalgamated with the mosquito control section, and in 1947 the Bureau of Vector Control was created. This period of time saw the most spectacular expansion that has ever taken place in California in mosquito control. Following World War II there were 30 local agencies - statewide. Collectively they covered only 5,000 square miles and they had an aggregate budget of a little less than half a million dollars. In a period of five years, the number of agencies doubled, the area increased from 5,000 to about 30,000 square miles and there was a manifold increase in the statewide expenditure for mosquito control. Today we have 62 local mosquito control agencies, collectively spending almost 9 million dollars and covering an area in excess of 40,000 square miles. The magic of the new organic insecticides, of course, also contributed to this expansion. In retrospect, many of us wish it had never happened for if these magic insecticides hadn't appeared, we wouldn't have resistance today and probably we'd have a different environmental appreciation. Nevertheless, we've had it; we've been through these insecticides. All the chlorinated hydrocarbons we've abandoned because of resistance and the organophosphorous materials (which I'm sure that Frank Kozlik will agree his fish and wildlife interests were relieved to see) also appear destined to go down the drain. Perhaps the most important contribution of the subvention program was the state standards and recommendations, which all of your agencies (I hope you'll agree) benefitted from. Until these standards and recommendations came into existence, there were no standards in California mosquito control relating to administrators, technical guidance or operational practices. Everything was informal. Everybody followed what the annual meeting suggested was the thing to do. They came, they listened, went back and practiced, came back, reported and did it again, but in terms of practice and in terms of uniformity and in terms of technological excellence, California had no reputation at that time. Following World War II, the combination of the local control agencies, the Bureau of Vector Control, its Advisory Committee, the University of California and others of technical capabilities collectively provided the basis for working out solutions to develop technological practices that have evolved over the years.

In 1952, who would ever forget if they went through it, an epidemic of encephalitis occurred. That year resembled this one with an immense snowpack, the water runoff, the mild spring and the big uptake of ***Culex tarsalis.*** It was physically beyond the capability of local programs at that time. What also contributed to the predicament was the failure of the chlorinated hydrocarbon insecticides, a failure which wasn't fully appreciated then. Mosquitoes were resistant to these materials. When we had a showdown and we needed them most desperately, they didn't come through. Anyway, over the years we have developed a gradual participation with the California Mosquito Control Association - a kind of cooperative arrangement.

However, the Bureau has always had a few other activities than mosquito control to cope with and these have become more and more demanding as time has passed. In 1951 with the creation of the Water Pollution Control Boards, now called the Water Quality Control Boards, solid waste management became an orphan. Who should be charged with the future responsibility in this area? The Bueau of Sanitary Engineering formerly had this charge, because strangely enough the by-products of living were all defined as sewage. When sewage was re-defined, refuse management, that is, solid waste management was completely overlooked. So, the Bureau of Vector Control was administratively charged with this responsibility. In 1951 the Bureau was given one man to handle the statewide responsibilities of solid waste management.

We also acquired increased responsibilities in rodent control; in fact Professor Herms was a special consultant to us on rat control back in the late forties. We have had more and more such responsibilities assigned to us over the years without the benefit of additional staff. We've just had to "re-direct emphasis", the popular advice given to us today by the Department of Finance. We've been re-directing emphasis so long that we're getting muscle bound from attempting to stretch our staff. Every year we hear the same tune, "no increases", so we just go on attempting to do as best we can.

Now, let's look at the department, today. We are part of an environmental health and consumer protection program, alongside the Bureaus of Food and Drug Inspection, Air Sanitation, Occupational Health and Environmental Epidemiology, Radiological Health and Sanitary Engineering. The Bureau of Vector Control and Solid Waste Management is not as simple as it sounds for we have five components designated within the system of program budgeting. Regrettably, program budgeting doesn't lend itself to a biological program. Nevertheless, we're compelled to use it and I assure you that gray hair is a sympton of the system.

The five activities in the Bureau of Vector Control and Solid Waste Management include:

(1) Zoonoses Suppression - this relates to the diseases sustanied in animal life, which are transmissable to man and domestic animals via arthropods and such other animals as rodents, but principally insects, ticks, lice, fleas and mites. We attempt to utilize an alert system throughout the state, in which observers notify us of abnormal small animal behavior or dieoffs. This activity is referenced to plague, tularemia, Colorado tick fever, Rocky Mt. spotted fever, relapsing fever, typhus fever and a whole score of other diseases that are indigenous in the wildlife of California. Essentially the aim is to protect the recreationalist from a very unhappy summer disease experience.

(2) Wilderness Area Vector Control - in addition to diseases which threaten the recreationalist, there are some 1100 different species of animals, including mosquitoes, that we are attempting to protect the public against in California by either developing better technology to control them, or by advising the public on how to avoid them, or how to coexist with them. I refer to scorpions, spiders, kissing bugs, biting flies, ticks, tarantulas, rattlesnakes, or any other unpleasant animal you can think of that you've experienced or that the public is likely to experience.

(3) Community Area Vector Control - in addition to recreation and wilderness areas, community areas all have vector problems, particularly cockroaches, rats, mice, pigeons and household insects. We provide technical assistance to attempt to solve these problems, often working with other agencies. Community problems are increased by aging, the older the communities get the worse they get, the more accessible they become, the more they sustain animal life. Much of our work is attempting to stimulate action to be taken at the right place at the right time to keep community premises from being a hazard to the public.

(4) Solid Waste Management - as the Bureau's title suggests we are charged with solid waste management. We are now in the third year of a statewide planning survey supported by the federal government. We will develop a statewide plan for coping with the mounting - literally mounting - solid waste problem. In 1967 California produced 71.5 million tons of solid wastes. To give you an idea of how big that amount is, just imagine a hundred foot swath of wastes piled 30 feet high from the Oregon border line to Mexico. That's how much we produced in 1967, and every year it goes up. Every year the aggregate of wastes further overtaxes the existing facilities. The pattern of growth of California is so extended, so encompassing, that it is making disposal of wastes a has been concept. Our growing population that promises to double by the end of the century, related to the cost of land, projected into the future, makes the disposing of wastes in the future a pretty dismal outlook. Our only answer would appear to be that of regarding wastes as a resource and salvaging and converting them to utilizable end products.

(5) Water Related Vectors - obviously includes mosquitoes, but associated with the mosquito problem is another insect which has become increasingly more a concern, particularly in southern California. I'm referring to midges or gnats. Certain species are indicator organisms for water pollution and wherever water is impounded or wastes are turned loose in the most convenient stream midges will develop. There's a saying up in Marysville - flush your toilets often, Sacramento needs the water. Well this is a joke, yet its a sad commentary on the attitude of reckless abandon which has become the case not only in California but thoughout the world. We no longer can survive with such an attitude. These problems can't be solved short of an absolute reclamation attitude toward water. At present, we impound liquid waste to keep it from polluting a stream or underground water supply and thereby create an organically loaded artificial lake, which is a come-on for midges to the point that although they don't bite, they overwhelm you by their numbers. Orange County has had this experience, Los Angeles County has had this experience and a variety of other areas are having it in increasing amounts. So we are having to deal with this kind of a problem as a part of the water-vector control effort.

The University of California has the major research responsibility for vector activities in California. Our role in mosquito control research has been limited to implemetation of technological developments, but until results come along we can't implement. Otherwise, we continue to try to be helpful to local agencies, irrespective of what the situation may be.

Now, lets mention some of the things we are doing which you may not be aware of. You heard Harry E. Spires, Assistant Director, California Department of Agriculture, talk about a pesticide use agreement. Annually for three years this Agreement has been executed, co-signed as it were, by your agencies and the Bureau of Vector Control and Solid Waste Management. This is a voluntary basis of participation for proper pesticide usage endorsed by the California Mosquito Control Association and by the Department of Agriculture. It specifies what, where and how certain insecticides can be used and should be used and thereby why others shouldn't be used. It is a safeguard for local mosquito control.

We are also trying to be helpful in calibrating equipment to obtain the most effective swath pattern for getting results. One of the options to each agency is to outfit itself to accomplish this independently; or we can do it for a great number of agencies in collaboration with your staffs. I think the concensus attitude was given some years ago when the California Mosquito Control Association requested that three additional staff be provided us for this and other purposes. We're still waiting for those three people. The compromise plan that Jim Bristow urged our Director to support, (which he endorsed but was turned down again by the Department of Finance) now finds us no better off than before. The California Mosquito Control Association also recommended that we obtain four source reduction engineers to accomplish the progressive reduction of mosquito sources by engineering methods. This request has also been turned down. At present, we have one person whom we use half time for water projects consultation.

We interpose mosquito preventive considerations upon all water development agencies in California, be they federal or state, and we have been very successful in causing them to incorporate mosquito preventive features through this consultative service. But what happens to new water after it is delivered? Responsibility for this aspect of water resources development in California has yet to be accepted. There is no obligation whatsoever upon delivery agencies or using agencies to conform to any standards whatsoever. After a problem happens then you remedy it. You don't incorporate preventive planning to solve the need before the problem happens. Pretty poor economy I'd say, but nevertheless this is the modus operandi.

In support of local programs, we try to assist as best we can in devising record keeping systems, performing technical consultation and program reviews if you wish them. Elsewhere, we still are trying to help develop mosquito control in uncontrolled areas. We estimate 20,000 square miles of California must still come into organized mosquito control within the next 20 years if the public is going to be protected. You can't force this upon the public, but must wait for the proper time. Meantime there are small districts springing up here and there.

We have a number of joint activities. A substantial part of our role and responsibility is stimulating and encouraging other agencies to secure our objectives. We work collaboratively with the State Departments of Agriculture and Fish and Game. These Departments, our Department, the U.S. Fish and Wildlife Service, the University of California and the California Mosquito Control Association function together on the Mosquito Suppression Wildlife Management Committee. This Committee seeks to develop policies and technical concepts for preventing mosquitoes compatible with wild life management in the conservation areas of the state. We work with the Department of Agriculture in attempting to develop concepts of agricultural planning to minimize mosquito production. Sometimes the results are slow in coming but nevertheless we are still behind the scenes trying.

We also put out a monthly publication "California Vector Views." This covers the field of vector control. We try to provide information, both ecological and technological, that will help local programs solve problems.

Lastly, there are things happening in California that I as a program administrator am not pleased about. There is an unfortunate trend taking place in public health these days - that of separating environmental activities from other aspects of public health. Public health has been eminently successful in reducing communicable diseases related to the environment. Now the reward is a trend to implant these activities in programs other than public health, such as resources agencies. Perhaps the overall plan behind the scenes is to bring all these activities together in an "environmental" agency. We are now located in the "Human Relations Agency" which suggests that the environment isn't holding up very well. At the federal level, water pollution control activities have been turned over to the Department of the Interior. I understand everybody is displeased with this. An effort was made to take air sanitation away from the public health service, but was unsuccessful. What will be the eventual outcome? We'll just have to wait and see.

THE STATE DEPARTMENT OF FISH AND GAME - ITS ROLE AND INTEREST IN VECTOR CONTROL

Frank M. Kozlik

California Department of Fish and Game
Sacramento

The Department of Fish and Game has the responsibility for protecting and conserving the wildlife resources of this state. For wildlife to exist they need habitat, or food, water and cover. With California's ever-increasing human population, the competition for land is also increasing, and so we see wildlife habitat being converted to industrial sites, urban developments, and agriculture. Without a doubt one of our biggest jobs is to preserve the remaining habitat.

Most wildlife habitat does not produce many mosquitoes. Upland type that produces quail, chukar, partridge, doves and big game like deer, seldom creates mosquito problems. On the other hand, wetland habitat, or marches and ponded areas, provides homes for waterfowl and other water-associated wildlife, but it can also produce hordes of mosquitoes. It so happens that wetland habitat is also in short supply, and we are trying our best to preserve what little remains.

Why is this wetland habitat so important? It is important because it provides winter homes for most of the waterfowl that use the Pacific Flyway. It also provides food and living space for shore birds, herons, egrets, grebes, gulls and countless songbirds.

Each fall about 10 million ducks come to California. Their exact number depends on the success of the nesting season in Canada and Alaska. During periods of high production like 1956-58 as many as 15 million ducks entered the state. When drought periodically appears on the Canadian praries and reduces the nesting habitat, production falls and California receives only about 7½ to 8 million ducks. In addition to the ducks about one million geese migrate to the California wintering grounds. Most of these geese nest in the Arctic beyond any drought areas, and while habitat conditions are more stable, production can be affected by other factors.

Although California is primarily a wintering area some birds do remain in the state to nest. Each summer the adult and young birds total about 300,000 ducks and 25,000 Canada geese. Much of the duck nesting and all of the Canada goose nesting takes place in the Great Basin area of the northeastern part of the state. Another important nesting area is the Central Valley where "local" mallards make up most of the nesting birds.

All of the waterfowl coming to California are seeking suitable habitat, which will carry them through the winter. It has been estimated that at one time there were 5 million acres of wetlands in the state. Early accounts by the first Spanish explorers abound in descriptions of the vast marsh areas in the great valleys and their attendant hordes of ducks and geese. These marshes were formed by the overflow of flood waters along the principal rivers, which was caused by the fall and winter storms but then continued into the summer by the runoff from melting snow in the mountains.

Early development of the land for irrigation farming controlled the flow of water onto these ancestral marshes and later dried them up. Man then reclaimed this land and it, too, was dedicated to agriculture. In 1906 a U.S. Department of Agriculture land inventory showed that there were 3,420,000 acres of wetlands in the state. A similar survey in 1922 showed that under the economic pressures of agriculture, industry and urbanization these wetlands had dwindled to 1,179,000 acres. By 1954 the wetlands survey of the U.S. Fish and Wildlife Service showed that wetlands had been further reduced to 559,000 acres. Since then additional wetlands have dissappeared and there are now less than one-half million acres remaining. Of this remaining habitat about 175,000 acres are in privately owned duck clubs, while most of the balance is on the state and federal waterfowl areas.

These state and federal areas were acquired to preserve wetlands. The U.S. Fish and Wildlife Service has 12 national wildlife refuges in California that total about 200,000 acres. Our Department manages 8 areas that total over 50,000 acres. A joint agreement between the two agencies provides for the management of the areas with the following three major objectives:

1. To provide suitable habitat and living space, so that an adequate population of waterfowl will return to the northern nesting grounds in good breeding condition.

2. To provide adequate food to keep waterfowl from depredating agricultural crops.

3. To provide public hunting for as many hunters as possible.

This last objective has been expanded to include other recreational use such as fishing, bird watching and sightseeing.

When we first acquired some of our areas we were not too concerned about the mosquitoes that we might produce. Some of the areas were rather remote from habitation, and only our personnel living on the area were bothered by the mosquitoes. But in time the urban sprawl moved out to reach our areas and it was not long before we were accused of being the source of all the discomfort that mosquitoes can cause.

Now as we develop our areas to make them more productive for wildlife we also make provisions for mosquito control. Fields and ponds are constructed in a way to have good water control. With proper water management we can help control mosquitoes and grow better crops of waterfowl food plants. With good water management we can also help control the waterfowl disease of botulism.

Many of our cultural methods for growing food plants are dependent on water control. The main thing is that as we use water to improve wildlife habitat we do not produce a large crop of mosquitoes. Researchers have found that many plants that are good producers of wildlife foods also produce very few mosquitoes. Most of these plants are of the emergent type with naked stems and include the spikerushes, alkali bulrush, and also some of the pond weeds. On the other hand, there are many plants that encourage mosquito production and produce little or no food for wildlife. These are such plants as cattails, water hyacinths, water primrose and the milfoils. Both mosquito abatement personnel and wildlife managers consider these plants as pests.

The Department continues to view with great interest the efforts being made to use fish in the control of mosquitoes. It is encouraging to learn of the value some of you place in the role of fish in your control programs. We hope that solutions to some of the resistance problems may lie in the expanded use of these animals in integrated programs. As you may remember our Department participated in a cooperative program a few years ago to identify fish of potential value for mosquito control purposes. These fish were collected by mosquito abatement districts throughout the state.

One of our areas is helping out in the production of *Gambusia*. These fish can control mosquitoes, but many times there are not enough fish to handle the problem. This is especially true in the spring when fish populations have been reduced by winter-kill. To help carry fish over the winter we have made available to the Sutter-Yuba Mosquito Abatement District a series of ponds at our Gray Lodge Wildlife Area. In these ponds fish can be overwintered and then distributed in the spring to potential mosquito production areas. If additional efforts would result in the more effective use of this type of insect predator, we would be glad to work with you in a cooperative effort.

We also make provisions for emergency treatment oı mosquitoes on our areas, where it is evident that chemical treatment might be necessary. Each area budgets funds and service agreements are made with local abatement districts. In this manner we are ready for immediate action should treatment be necessary. Many people think that we are opposed to chemical treatment. However, the Department is very interested in working with the mosquito abatement districts in regards to their use of insecticides. We recognize that by encouraging the districts to help out in preserving marsh areas for wildlife we are in a sense advocating the use of chemicals rather than source reduction. We are also concerned about the hazard to fish and wildlife that can result from the use of insecticides. It is quite obvious, therefore, that we have an obligation to assist you in developing insecticide usages that are effective, yet not harmful to fish and wildlife.

Our major role in this regard is to evaluate the side effects on wild animlas of new control chemicals or techniques for mosquito control before they become operational. In this way we hope that by the time the control procedures have been approved for the district's use the chemicals can be applied as directed without unwarranted side effects. In fact the intent is to incorporate a rather sizable safety factor into the recommendation to allow some leeway in applications before adverse effects can occur.

However, as the problem of insect resistance increases there has been a tendency to seek solutions to this problem by increasing application rates of available insecticides or through the development of new materials. New insecticides, like Dursban® for example, are highly toxic to both mosquitoes and fish at low levels. If new highly toxic materials are to be used, or if the application rates of insecticides in current use are increased the safety factor that provides protection to fish and wildlife will be reduced. This means that chances of unwanted side effects occurring will be greater and that additional care in the selection and use of insecticides will be required if losses of nontarget animals are to be avoided. We believe that closer cooperation between conservation agencies and those agencies involved in mosquito control will be required to prevent these problems from actually developing.

To that end we are becoming more familiar with the operations and problems of the districts. For example, our fisheries pesticide specialist had the opportunity to observe mosquito conditions in pastures throughout the Central Valley during several trips made in connection with the proposed use of Dursban for mosquito control in pastureland. We learned a great deal about the problems of this type of operation from contacts made with abatement districts during these trips. We anticipate that we may be working with some of you soon, if plans materialize for an assessment of higher application rates of parathion for the control of *Anopheles* mosquitoes.

Besides managing our own lands we are also interested in preserving habitat on private lands. The value of private duck clubs in helping to preserve the state's little remaining wetland habitat cannot be overlooked. Their very existance places a high economic value on the habitat and prevents their reclamation and development for other purposes. In all, there are about 1,000 clubs and they control about 300, 000 acres of land. However, these lands are not thoroughly developed so that only about 175,000 acres can be considered as wetlands. While many have damned duck clubs as being the stronghold of special sporting privileges, the Department is interested in the amount of habitat that the clubs are preserving. In fact, the objectives that many of these clubs are accomplishing parallel those of state and federal areas, namely that of maintaining habitat, controlling waterfowl depredations on agricultural crops and providing hunting. Naturally in the case of duck clubs their main objective is hunting, but the other benefits to the waterfowl resource are present nevertheless.

One way to compensate for the loss of habitat is by increasing the carrying capacity of the remaining wetlands. Many of the duck clubs are only partially developed, but by improving their holdings the clubs will be able to carry more birds. The Department of Fish and Game technicians and the soil conservation districts encourage duck clubs to improve their habitat by proper water manipulation, raising aquatic foods, and controlling the undesirable cattails and tules. As we do on our own lands we try to have clubs use management practices that will control mosquitoes. We are well aware that many duck clubs, through poor management of their water, can become a public nuisance by raising mosquitoes. Here again, we would rather see mosquitoes controlled by a safe chemical means, than to have habitat destroyed by source reduction.

As water is distributed to new areas of the state by the California Water Plan we are hopeful that wetland habitat will be improved. The plan does have provisions for the benefit from drain water. Water that has become too alkaline for further agricultural use will still grow waterfowl food plants. Such water can be a boon to duck clubs that are barely existing on a scant supply of high-priced well water. It will create better habitat and improve conditions for the waterfowl resource as well as other water-associated wildlife.

It is also apparent that with the wide distribution of water throughout California, the problems of insect resistance and urban sprawl will combine to make the difficult job of mosquito abatement even more difficult in the future. However, we believe that by working together the various agencies associated with mosquito control can develop programs that will provide effective mosquito control without harming fish and wildlife.

EXPANDED SCOPE IN VECTOR CONTROL BY MOSQUITO ABATEMENT AGENCIES

Allan D. Telford
Marin County MAD, San Rafael

Expanded scope in vector control at the local level has been given a lot of consideration within the California Mosquito Control Association and the American Mosquito Control Association for ten years or more, and as with most matters of association policy there is a divergence of opinion. CMCA policy and unanimity of opinion on matters affecting district performance are important to us all. Nevertheless, we districts are beholden to our local taxpayers and sometimes we must make policy decisions on matters that the CMCA is undecided about. So, for the sake of our discussion let us make believe that I have to consider expansion of the Marin County Mosquito Abatement District's scope and talk about what my problems might be.

We are first of all a public service, tax supported agency. Consequently, any expansion by our District must be based upon either a demand or a need of the people of our District. The initiative for expanding should therefore come from the people.

Our first problem then is, are our people aware of the services that their mosquito abatement district is authorized to provide for them and is the district equipped and competent to provide a particular service most effectively and most economically. Should the matter of expanded scope seem necessary, it is then my obligation to inform my people of our capabilities and give them an estimate of any additional tax a service might cost them. With this information the people of my District could decide what kinds of services it would be practical for them to ask for.

With our crew competence is not a problem. Our equipment could be brought up to standard, at minor expense, for any job that would fall within our perimeter of responsibility.

A second, and difficult problem is, what kinds of services fall within the perimeter of our responsibility? I know that throughout the country, mosquito abatement agencies do many different kinds of jobs ranging from weed control to vertebrate pest control. We here in California must first consider what we are authorized to do by our State Health and Safety Code. Taken out of context, the code says that a mosquito abatement district may "take all necessary or proper steps for the extermination of mosquitoes, flies or other insects" and "abate as nuisances all stagnant pools of water and other breeding places for mosquitoes, flies or other insects."

Technically and officially the Marin District is commissioned to abate only mosquitoes and yellowjackets. The history of mosquito borne human disease in Marin County consists of two cases of encephalitis about which there may be some question of origin. We are suppressing mosquito species that include vectors but whose individuals here have transmitted little or no disease to humans. Yellowjackets, our other chief concern, are not really vectors. Nevertheless, several deaths and much serious discomfort have occurred from anaphylaxis due to yellowjacket stings in our District. The Marin County MAD, at least at this time, deals with acute nuisance problems, not vector problems.

Now that you know what we do in Marin let me get back to the Health & Safety Code and a more generalized discussion of scope. It is reasonable to assume that the code was composed primarily for mosquitoes, flies and other insects which are vectors or may in other ways directly affect our physical comfort. Nevertheless, it does suggest a wider range of targets, a non-specific category called, "other insects." The code also allows us a very wide latitude for control action that goes beyond recommendations, advice and law enforcement.

I look at our position this way. The Marin County MAD is specifically instructed by the State Health & Safety Code, is best equipped and most competent to abate whatever kinds of insects the citizens of its District deem, not only vectors, but public nuisances in any respect. To the best of my knowledge our District is the only public agency in the

County that is properly authorized and equipped to go out into the field and take all necessary steps to exterminate insect pests. Our services, therefore, should be given serious consideration by the people and their legislators for use against any kind of insect that is a public nuisance or a destroyer of property. In addition, I would wish to broaden the scope of the code to include the abatement of all arthropod pests, not just insects. Thereby, the abatement of spiders, mites, ticks, scorpions and other such undesirable animals might also be officially sanctioned.

To recapitulate, I believe that the Marin MAD's responsibility should go beyond vector control. However, I also believe that it should be restricted to arthropods generally agreed upon to be public nuisances or bothersome to man, his animals and other belongings. That is, principally in an urban or domestic sense, as distinct from the commercial plant industries. (This responsibility might include such things as household pests, pests of stored products, pests affecting institutions and government offices – perhaps routine treatment of publicly owned plants like street trees or shade trees.) Our District, without a doubt, could take on other pest abatement problems and do an excellent job. However, I do not believe we are in a position to deal with pests other than arthropods without special contractual considerations.

Of course, with committments of the nature that I have described, there immediately would loom a mountain of policy problems. Would these services impinge severely upon private enterprise, and if they would, could they be justified in any case on the basis of public demand, economy and greater reliability of results? Would any services within the district's perimeter of responsibility be duplicated or preempted by other public agencies. Could another agency do a better job and so on.

The Marin County MAD has had excellent rapport with other local agencies, the CMCA, private pest control operators and the public. We intend to maintain our good standing. We are well aware of the need for interagency cooperation and understanding, especially with respect to expansion of scope.

Some other districts have made much better headway with some of the problems of expanded scope and improvement than we have. We need research information to help us solve our localized problems. It doesn't look like the University or the Bureau of Vector Control or anyone else is going to be able to work on the regional problems of one or two districts. I hope that we may broaden our scope to include limited, much needed, research in our own backyard. First, this is a matter for our District's people to think about and decide upon. If they would want district research on narrowly regional problems, then other local agency or neighboring agency cooperative projects might be considered. As we all know, there are several other avenues to try toward the satisfaction of a research need (means to raise money that is). Briefly stated, I would encourage district interest and district participation in localized research projects to solve localized pest problems.

I shall mention one kind of research because I think it is very important to us in Marin. That is our role in the pollution of our environment and our possible disruption of established and perhaps important ecological systems. Our control efforts cover large areas of relatively wild and natural terrain. Our lack of information in this regard worries me.

In the Marin District over the past few years we have done as little buck passing as possible with service requests for general information and advice or even with crank complaints. I think the scope of our activity as a pest advisory and perhaps a pest identification center can be improved.

What I have said here this afternoon is kind of a district oriented view of such things as expanded scopes and vector dangers. I have been general in coverage and provincial in attitude. This is because I must be interested in how these ideas will work out in my District first before I can relax with their global or celestial implications.

SUGGESTED FUTURE FINANCING OF MOSQUITO RESEARCH

Arthur L. Cavanaugh

Coachella Valley Mosquito Abatement District, Thermal

California mosquito control is slowly slipping into a crisis through insufficient research. Unless more money is made available for expanded research on new materials, methods and application, mosquito control in California will experience real difficulties in the very near future.

Speaking from the experience of our District in research, grants-in-aid to the University may offer the quickest way to alleviate the problem, along with an extensive educational program with the legislators in Sacramento.

This program could or should be set up through the CMCA, although I am told that, as the contracting agent for the districts with the University of California, the bylaws of the Association would have to be changed.

Although this may seem complicated I believe this is the way to go. The Association now has a research committee who could ask the districts to send their problems to them, to then be screened in the idea of obtaining the most important areas of research.

If the districts will put up approximately $100,000 as matching funds with the State of California, I believe it will be much easier to obtain money.

Our District gave the University of California, Riverside, $40,000 plus men, equipment and vehicles this past year.

It does not appear at the present time that there will be any money granted on new items inserted into the budget this year. This will give the districts a year to work in the development of a research plan.

Some fifteen years ago the control of eye gnats in our District was strictly chemical. Our board approached the University of California, Riverside, with a grant-in-aid to start a project on the control of *Hippelates* eye gnats. They worked these many years. I don't believe they ever became disillusioned as to the final outcome for control. I can truly say that the District had trouble explaining what was being done. Today Dr. Mulla can say they have made a breakthrough and full control of the eye gnats is about two years away. Not only the District but the people of the valley, that have been paying taxes all through the years, feel that the money for this research is the best money they have ever spent. In the long run it will be a savings of millions of dollars in property values and will assure continuing progress in the valley.

I think that it would be well to bring up at this time that each research specialist like Dr. Mulla and others like him cost $50,000 per year. This does not include buildings and equipment, just staff and supplies.

At the University there are complete libraries, chemistry laboratories and others, or the staff that the investigator can confer with. No district regardless of its size or money can do a comparable job in research compared to the University. One of the things I believe you men should think of is this: You now have a good start in the staff of mosquito research in the state. If for some reason financing is not forthcoming and these men transfer to other projects or leave the University and the research projects are interrupted or discontinued, it will take many years and more money in the long run to re-establish the research facilities that you now have available.

I beg of you to consider the financing of mosquito research with grants-in-aid to the University. Compare it to the disaster which will surely come.

VECTOR CONTROL ACTIVITIES IN THE PACIFIC NORTHWEST

George E. Runyan

Columbia County Vector Control District
St. Helens, Oregon

Before going into any discussion of vector control activities, a review of the 1968 record of vector-borne infections in the Pacific Northwest might be in order:

1. There were three incidences of tick-borne relapsing fever totaling ten cases, including one fatality in east-central Oregon. The vector in these cases is thought to be a species of *Ornithodoros* tick.

2. Western equine encephalitis in Oregon rose radically last year in the equine population. For comparison, in the period 1960 through 1967, there were 191 cases in the state, of which 42 cases occurred in Jackson and Josephine counties. In 1968 there were 65 diagnosed cases in the state, of which more than 40 came from Jackson and Josephine counties. No human cases were reported last year. *Culex tarsalis* is the established vector in Oregon.

3. Idaho has reported one case of human bubonic plague in 1968. This was from the community of Salmon in eastern Idaho. The victim, a hunting guide, had a record of recently skinning out a snowshoe rabbit prior to his onset and it is felt that this is another of the increasing number of infections stemming from sylvatic sources. The actual point of infection was apparently the ranch which is used as a base for hunting trips and is about 50 miles southwest from the community of Salmon, as the crow flies.

4. In Oregon, wild rodents checked for the presence of *Pasteurella pestis* yielded negative results. Not that the state is plague-free by any manner of means. It probably would be safer to say that the sylvatic infection had possibly gone into a decline for the time being or that the trappers just did not catch any infected specimens.

5. Rabies in Oregon continues to be a worrisome problem since the reservoir (bats) is so well established although no human cases were reported this past year.

In the matter of vector control activities in the Pacific Northwest, there is an increasing demand for control of mosquitoes and other pests throughout the area generally. Residents of what can be termed the "Last Frontier" have come to the realization that it is not necessary to tolerate these pests and that control or elimination produces not only an increased sense of comfort and well-being but certain economic improvements as well. Going back to the "increasing demand" for a moment, this seems in a large measure to stem from the various newcomers who have lived in other areas of the country where vector control has long been established and who have felt that vector control is a natural function of local government. Their continued criticisms and comparisons eventually have an effect on the "natives" who finally begin to wonder about the advantages of this type of program.

In Oregon, because of this demand, there are now seven vector control districts, two of which came into being in 1968. Additionally six counties finance vector control activities through their respective health departments. It should be noted that the statute governing vector control specifies that mosquitoes and flies are public health vectors. It should also be mentioned that the Oregon statute makes formation of a district relatively simple when pushed by a group of determined citizens.

In Washington and Idaho the statutes of these two states do not make the formation of a district so easy as in Oregon. Washington law, for example, permits the formation of mosquito control districts in only seven of the state's thirty-nine counties. All of the seven are located in southeastern Washington. In British Columbia organized mosquito control is practically nonexistent. In the main, what mosquito control is accomplished is through the hiring of commercial pesticide applicators by communities or neighborhoods to do some adulticiding during the active season.

In the introduction and use of *Gambusia affinis*, there has in the past been a lot of opposition by the fish and game officials. This opposition is beginning to lessen and it is hoped to have it eliminated soon. In Oregon for the past four years, *Gambusia* have been spread widely and legally although permits from the Fish and Game Commission are still required to move them. In 1968 the Idaho Department of Health introduced them into a holding pond for observation by the Idaho Fish and Game Commission. In Washington in 1968 the Fish and Game Commission of that state permitted their introduction by the Washington Department of Public Health into certain selected areas of that state. In this introduction the Oregon State Board of Health and the Columbia County Vector Control District of St. Helens, Oregon acted as the suppliers.

MOSQUITO CONTROL BY AIRCRAFT IN MERCED COUNTY

Douglas C. White

Merced County Mosquito Abatement District, Merced

The use of aircraft began in Merced County in 1946 following the establishment of the District on a county-wide basis covering an area of 1995 square miles. It soon became evident that an operation of this size would require the use of aircraft to augment the ground spray program. Consequently, in 1946 the District contracted for its first spray plane. This plane treated approximately 8,000 acres during the 1946 season. The following year the District purchased its first airplane, a 75 hp Aeronca Champion equipped with a 35 gallon spray tank. In 1947 86,000 acres were treated by the District owned airplane and the rented plane.

From this early beginning the Merced District has utilized aircraft as its primary control tool accounting for 95% of the spray work. In keeping with this policy the District purchased a Bell G-5 helicopter early in 1966. The motivation behind this move is basic, that, in order to keep pace with the increased land use and the associated increase in mosquito problems, modern equipment and methods must be employed. To briefly illustrate this growth the District treated 86,000 acres in 1947, 162,000 acres in 1959 and 267,000 in 1968.

Since the introduction of the helicopter into Merced's program we have received numerous requests from mosquito abatement districts and other governmental agencies for cost of operation data. Therefore, I would like to comment on helicopter versus fixed-wing costs as experienced by our District over the past two years. Table 1 shows a comparison of these costs.

Table 1. Comparison of Costs of Fixed–Wing aircraft and helicopter in the Merced County MAD, 1967-1968.

Fixed–Wing	Total Acreage	Cost/A.	Average Acres/Hr.
1967	167,219	0.288	154
1968	184,168	0.262	181
Helicopter			
1967	99,069	0.294	234
1968	84,872	0.333	236

These are operational costs and do not include the insecticide costs. All the helicopter work was done at an application rate of ½ gallon to the acre with a 100 foot swath. A limited amount of ULV was performed by one of our fixed-wing aircraft. Hourly costs were calculated at $67.00 for the helicopter and $45.00 for fixed-wing.

Commenting on the area of surveillance and inspection by helicopter, in the spring of 1967 we initiated an annual larval survey of a 250 square mile area located in the eastern portion of Merced County. This is an area adjacent to the foothills of Mariposa County running north and south the length of Merced County with a width of about 8-10 miles. Seasonal rains leave this area pockmarked with rain pools and represents a sizable potential for *Culex tarsalis* production.

The first survey was initiated in the last week in May of 1967. We were able to visually inspect and random sample the 250 square mile area in 3 hours and 5 minutes. This includes travel time from the Merced Headquarters to the field and time for one refueling. We averaged 2-3 minutes per stop to inspect and collect larvae.

The second survey was started late in March of 1968 and reflects the drier condition present at that time. Again we inspected and collected larvae on a random basis throughout the entire area in 3 hours and 40 minutes, with a 2-3 minute average stop time.

Also, in the spring of 1967 we tested a clover leaf pattern for helicopter inspection flights that was devised by Thomas Mulhern. The plan proved to be a workable method to rapidly survey large areas.

Inspection by helicopter, as a part of our regular program, has been on a limited scale. We try to have all ground operators make an occasional aerial survey of their zones. Usually the operator makes a visual check of his area noting any sources that he has not seen from the ground. In some cases, time permitting, he will land and make an actual inspection.

We hope to establish a helicopter zone. This will be an area which will be inspected and controlled entirely by the helicopter.

AERIAL SPRAY APPLICATIONS OF LOW VOLATILITY AND FINE ATOMIZATION FOR MOSQUITO CONTROL

N.B. Akesson, W.E. Burgoyne, W.E. Yates and Khairy Aref

Agricultural Engineering Department
University of California, Davis

A series of test runs made over the past three years using fixed and rotary wing aircraft indicates that when chemicals having high toxicity to mosquitoes (larvae and adults) are available it is possible to apply volumes of a few ounces per acre in coverage of as little as 50 drops per square foot and still obtain a reasonable control. The chemical must be effective at low dosage rates either in water for larval control or in air as a fumigant and deposited on foliage for contact control. We have shown through several years' work that air transport of small aerosol size spray particles (less than 50 microns) does occur from any spray application (Akesson and Yates 1964) and that the movement is a function of (a) local weather, particularly with low velocity and a temperature gradient of highly-stable inversion type (b) particle or spray droplet size and (c) the formulation of the spray or the relative amount of non or low volatile portion in the spray mix. These three factors have been investigated singly and collectively to determine what type and amount of downwind transport would result. However, another factor was introduced which has been used by others in the past for large area or blanket drift-spraying; namely, high altitude (200 to 2000 ft) release. The wind velocities measured in a vertical manner generally show an increasing pattern or gradient as we move upward from the ground cover influence. It is also found that stratified layers of air may be moving at different velocities and even at 180 degree different direction. This alone makes prediction of ultimate deposit of spray released from high altitudes difficult, but the attractiveness of large area coverage made it of interest to us to proceed with some test runs.

We approached the problem of large area treatment for mosquito control in California's interior valleys on two premises for safe usage: (1) that relatively low mammalian toxicity materials would be used and (2) that application rates would be significantly lower than usual agricultural insect control and so low that environment residues would not be significant. Two materials were used throughout most of our tests, fenthion (Baytex®) and Dursban®; these are both low toxicity organophosphorus materials. Both fixed and rotary wing aircraft were used and in general no comparative testing was done, but technical volume rates were applied varying from 0.5 ounce to 12 ounces per acre at which levels contamination of forage, soils and run-off water would, hopefully, not occur. Not all applications were at the technical level, some plots being treated with dilutions using diesel oil and, in some cases, other low evaporative materials for specific studies.

Figures 1 through 4 illustrate the various aircraft and systems used. Figure 1 shows the Turbaero electric motor-driven, multiple disc-type spinner. Four of these were used on the Bell Helicopter shown and also were used on a Piper Pawnee. A small diameter trailing edge boom and an 8-nozzle technical volume system was also fitted to a Piper Pawnee aircraft. Figure 2 shows the electric drive gear pump and a 5 gallon stainless steel tank for technical volume work mounted in the Pawnee aircraft just forward of the fire wall. Figure 3 is of a belly pod and short boom mounting in a Piper Aztec twin engine airplane. The forward portion of the belly pod has an interior fitted spray chemical tank and the after portion has an electric motor and gear pump assembly as in the Pawnee. The short boom can be seen under the belly pod and was also fitted to the tail for naled (Dibrom®) spraying. Figure 4 shows the tail boom mounted for corrosive sprays on the Pawnee. Here the liquid was carried from the pump mounted forward of the fire wall, back to the tail assembly. Eleven nozzles were placed on this boom as can be seen.

The nozzles used on all of our aircraft tests were directed either 45 or 90 degrees downward to the slipstream. Pressure varied from around 30 to 60 pounds per square inch (psi). Forty psi with the 80 degree fan nozzles (Spraying Systems 8001 to 8002 and Delavan FS4) give a volume median diameter (vmd) of around 200 microns when petrochemical materials are sprayed with no water. Smaller nozzle sizes to the 80005 or 800067 (fan types) reduces drop size to about 125 microns vmd with the nozzle directed 45 degrees to the slipstream. The orifice and swirl plate cone nozzles used were D3-23, a 3/64 inch plate orifice plus a 23 swirl plate. Operated at 40 psi, and at 90 degrees to the slip-

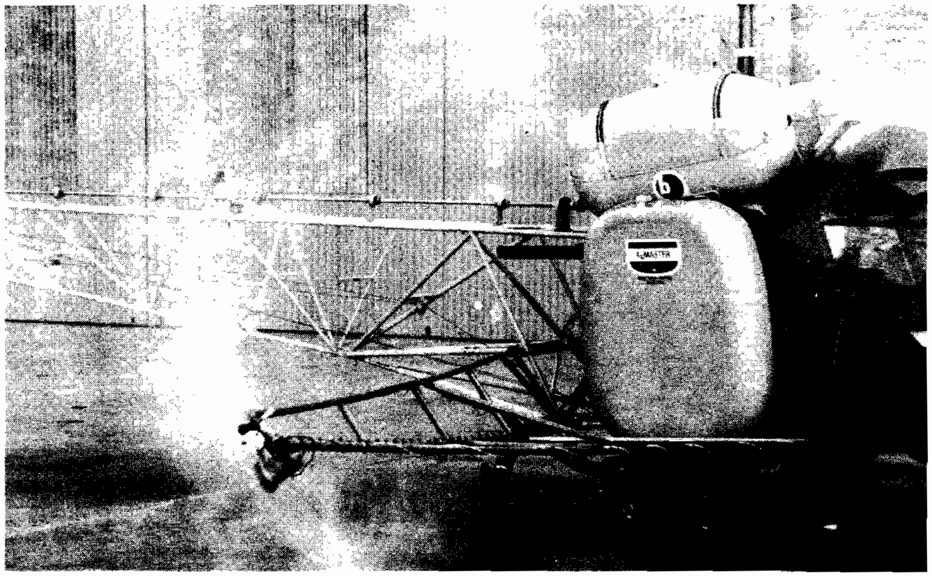


Figure 1. Turbaero electric motor driven multiple disk spinner attached to Bell helicopter.

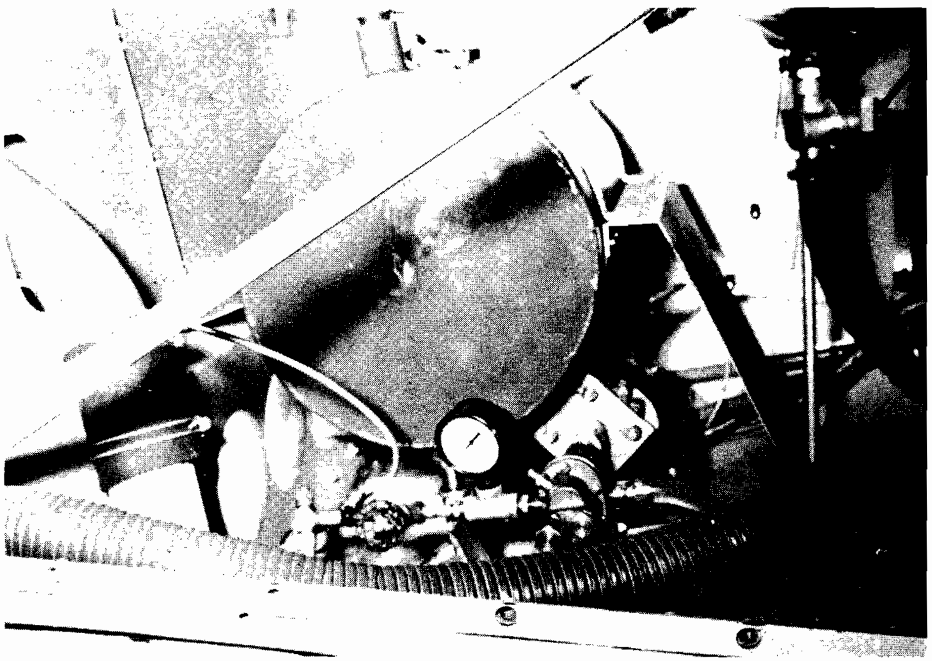


Figure 2. Electric drive gear pump and stainless steel tank in Piper Pawnee aircraft.

Figure 3. Belly pod and short boom on Piper Aztec aircraft.

Figure 4. Piper Pawnee with tail boom mounted for corrosive sprays.

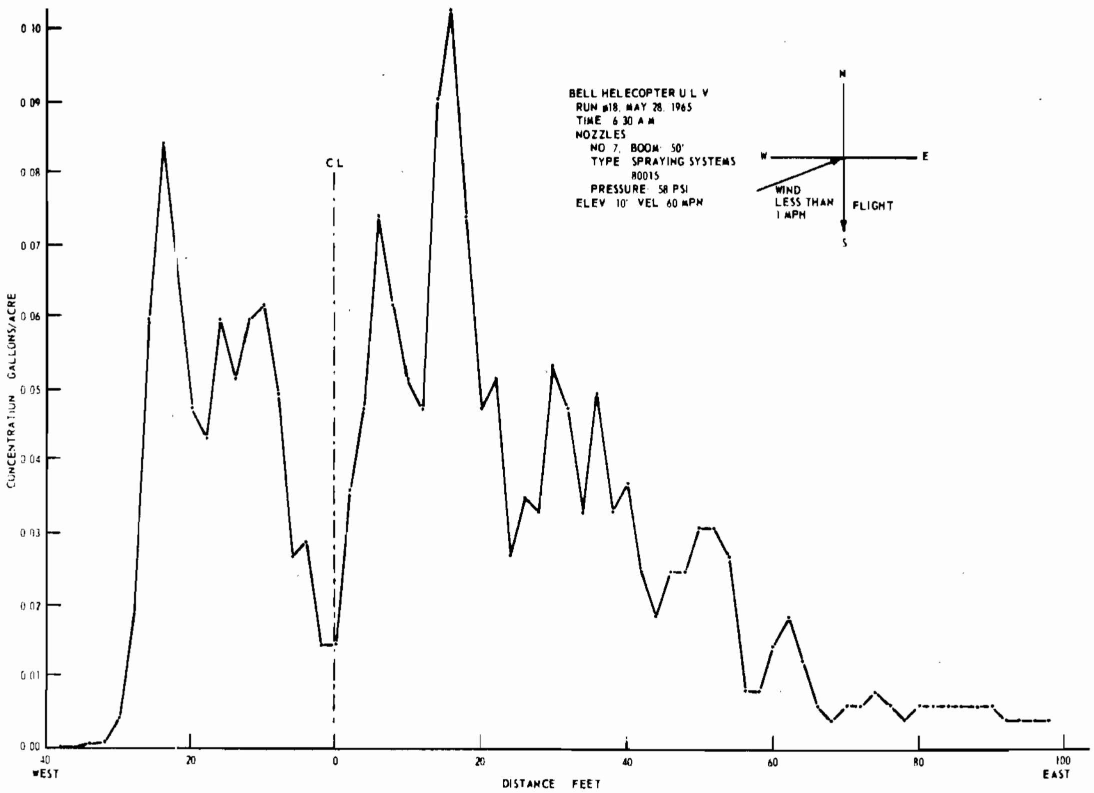


Figure 5. Spray pattern from Bell AG-4 helicopter with 50 foot boom and 80015 fan type nozzles.

stream these gave an estimated 80 to 100 microns vmd. Certain preliminary tests were run with D4 and 6 orifices with 45 size swirl plates and 250 microns vmd would be expected from these.

Several spinning screen, disc and plate devices were examined and tests on one of these, the Minispin, indicated a vmd of about 130 microns was achievable when the spinner was operated at 8000 revolutions per minute (rpm) in a 100 mph airstream. Since this air velocity was not available on the helicopter (maximum speed around 60 mph) we had to examine various electrically driven spinners and decided on the Turbaero as made by Edward Bals Manufacturing Co., Bromyard, England (Figure 1). During the 1967 tests this device was field checked and a drop size range of approximately 70 microns vmd was found.

Formulations - As indicated earlier, two materials, Baytex and Dursban, were used as basic test chemicals. These were applied in technical volume, about 40 to 70% active ingredient (ai) concentration, or were diluted further with diesel oil and other materials for certain tests. The Colusa tests, August-September, 1968, used Dibrom 14, 85% ai material, at 14 pounds per gallon.

Swath Patterns - Initially, a series of swath pattern studies was made on the aircraft we intended to use for the test series. These included the Hughes and Bell helicopters, and the Pawnee and Stearman fixed wing planes. Figures 5 through 8 show the patterns that can be expected from the aircraft and with the type of atomization used. Unlike coarse spray (over about 250 microns vmd) the fine, more easily airborne particles respond to the air wake of the moving aircraft and are displaced in a wide pattern largely unrelated to the boom length or wing or rotor span (Akesson and Yates, 1964).

Figure 5 is of a spray pattern from a Bell AG-4 helicopter with a 50 foot boom and using 80015 fan type nozzles operating at 58 psi. The spray liquid was dyed water and the boom height was about 10 feet above the ground. The spray particle size was about 200 microns vmd and the pattern is quite distorted from both the rotor wash and a slight wind (less than 1 mph) from the side. A 90 to 100 foot swath would appear possible at a 0.03 gallon per acre (gpa) or about 4 fl oz/acre rate.

Figure 6 is a similar helicopter with 2 Turbaero spinners (37 feet apart) and shows that with the considerably finer diesel oil spray (about 70 microns vmd) the useable swath width has increased to about 200 feet with the 0.03 gpa application rate.

Figure 7 is of a Piper Pawnee aircraft using FS-4 fan nozzles at about 30 psi (vmd about 200 microns) airspeed of 90 mph, and using a summer spray oil, (Chevron Chemical Co., H-Stock).

These runs, made over bare ground and sampled from spray caught on 3 x 6 inch plastic plates, when compared with a technique using bioassay analysis of mosquito larvae show among other things, a wider swath for the bioassay technique reflecting in part the accumulative effect of several overlapping swaths. The bioassay is done by placing water filled cups across the aircraft swath and exposing these to the spray. The sprayed cups are then taken to the laboratory where larvae are placed in them. The level of active chemical can be determined by the rate at which the larvae are killed (Gillies et al., 1968). Figure 8 shows a single pass (dotted graph) and the results (solid lines) of spraying 3 swaths at 250 foot spacing. The Bell helicopter with Turbaero spinners gave a remarkably uniform kill in the cups over the interval shown. Similar runs with the Pawnee aircraft indicated a useable swath of about 175 feet, but no clear cut pattern could be established on a single swath for the fixed wing plane (Womeldorf and Gillies, 1968). On this basis of larval kill the swath from the helicopter with spinning atomizers was set at 250 feet and of the Pawnee at 150 feet. It is obvious that with the fine spray considerable movement will take place and the actual swath width becomes somewhat academic. The total application per plot area, plus recovery of chemical or bioassay, then becomes much more significant.

Weather Factors - It becomes very evident that the control of mosquito larvae, or lack of it, will be dependent upon factors other than a clearly definable swath width as long as finely atomized materials highly toxic in minute dosages are used. As resistance develops, as has been the case with such materials as DDT and malathion, then the dosage becomes more critical and useable swath patterns become more identifiable.

Probably the greatest unknown factor in technical volume applications is the micro-weather. Clearly established relationships can be shown between the drift losses from applications of normal coarse spray of emulsifiable materials and the less evaporative, but finely atomized, technical sprays and the effect of different weather patterns on each of these (Yates, Akesson and Coutts, 1967). With agricultural sprays we are primarily concerned with keeping as high a percent of the spray as possible in a specific narrow swath, but we are also concerned with dissipating the small percent of very fine particles as quickly as possible by diluting them in the downwind environment. To insure successful technical volume applications we need fine spray particles for wide swaths, but we do not want high winds or temperature lapse (turbulent weather) conditions to move the fine spray away. In these circumstances temperature inversion conditions and low winds (under 5 mph) are most desirable for retaining the spray in the application area. As long as dosages are low, of the order of 0.1 lbs/acre, or 1/10 to 1/20 of agricultural rates, the levels of residues, even on directly sprayed crops and pastures, remains in the order of 1 to 2 ppm (parts per million) within 6 hours after spraying, and an average of less than 0.1 ppm 17 days after spraying (Myers, Lewallen and Nobe, 1968). Residues on rice (0.025 lbs/acre) after applications of Dursban and on grass (0.05 lbs/acre) showed from 0.32 to 0.64 ppm and 1.5 to a high of 8.0 ppm at 0 days after spraying. Within 6 days all levels had fallen below 0.2 ppm for the 0.05 lb/acre treatments, and around 0.07 ppm for the rice treated with 0.025 lbs/acre. No residues were found above the detection level (0.0005 ppm) in any tailwater and in treated water no levels above 0.0031 ppm were found even at 0.1 lb/acre application (Winterlin, Mailanen and Burgoyne, 1968). However, Dursban can be lethal to fish such as bluegills at very low dosages (10 ppb), and tests run on caged fish during the trial runs at Colusa showed that the 0.025 lb/acre rate may be close to the tolerance level of the fish population (Linn 1968).

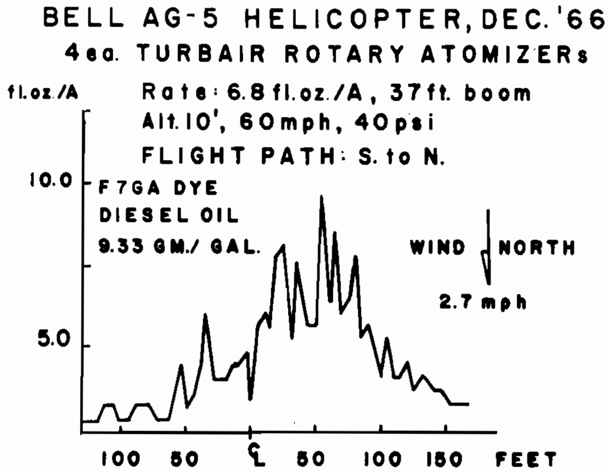


Figure 6. Swath pattern of Bell AG-5 helicopter with two Turbaero spinners.

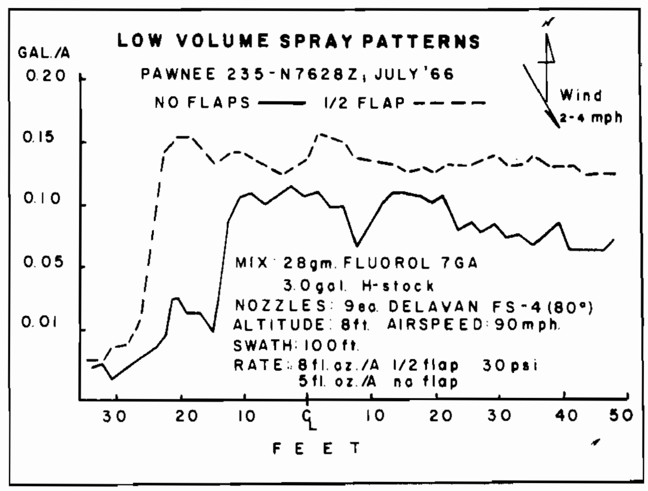


Figure 7. Spray pattern of Piper Pawnee with FS-4 fan nozzles.

Field Test Runs - Following the initial swath tests, small field test plots were put on in 1965 and 1966 to establish the operating parameters and techniques including swath widths and weather factors. In 1967 a large scale program was designed to protect the town of Colusa by spraying of several thousand acres of commercial rice in the area in cooperation with the Colusa MAD and several governmental

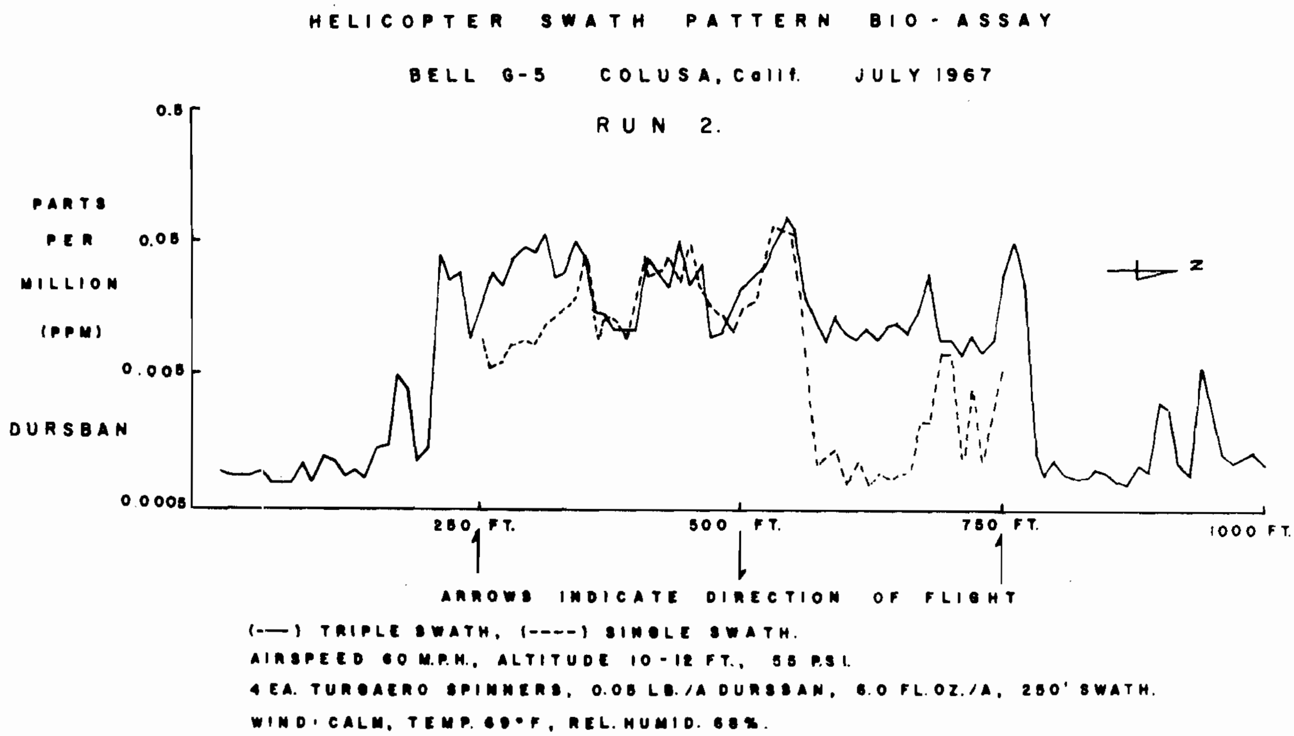


Figure 8. Swath patterns of Bell AG-5 with Turbaero spinners, comparing single and triple swaths.

agencies. Unfortunately neither Dursban nor Baytex was permitted at that time on the commercial rice so the tests were confined to 2 wildlife refuge areas, the Delevan refuge of 650 acres (Dursban) and the Colusa refuge of 550 acres (Dursban), plus two pastures of 660 and 1750 acres (Baytex), as well as a hunting club of 3750 acres and 100 acre field of seed rice (Baytex).

During 1968, trials of a unique nature were conducted at Bakersfield near the Kern Wild Life Refuge. Many cooperators were involved including the Kern MAD, State Bureau of Vector Control and the Disease Vector Control Center of the U.S. Naval Air Station, as well as several chemical companies and several departments of the University of California. For these runs an attempt was made to evaluate the effects of high level flights (1000 and 2000 feet) on the downwind drift and fallout of finely atomized Dursban spray. The bioassay technique was used as well as live mosquitoes in cages. Aluminum plates were laid out for gas-liquid chromatography (glc) at Fresno and Mylar plastic sheets for glc at Davis. Drop size and numbers were taken on Kromekote® paper and magnesium oxide slides as well as on glass slides (Akesson and Burgoyne, 1967). Air samples were taken with cascade impactors to evaluate the air carried portion of the insecticide. Application was with a Kern MAD aircraft, a Piper Pawnee (PA-25) with an electric motor-driven system (Figure 1). Nozzles were fan type (8002) and initial drop size was probably of the order of 200 microns vmd.

Three test runs were made, two flown at 1000 ft., and one at 2000 ft. The data shown in Figure 9 (altitude 2000 ft.) indicate that from 4000 to 14,000 ft. downwind from the spray path there were significant levels of Dursban fallout. The four graphs shown indicate difficulties in comparison of data on residues when different analyses techniques are used. The heavy black line is glc data obtained at Davis and the dot-dash line is similar data obtained at Fresno. From previous experience we have come to expect that the bioassay technique (upper dashed graph) reads considerably higher than direct residues analysis. The differences between the two glc graphs are largely happenstance as it can be seen that the peaks of one curve (except at 14,000 ft.) happen to be the only sample points for the other. The adult percent mortality curve, shown as the heavy dashed line, follows the Fresno glc data quite well and is not averaging more than about 30% control. However, this is over a very large swath area of nearly two miles and is remarkable for even the rather low result which appears to have been at least partially accomplished by fumigation action of very small particles in the air.

Weather conditions were near a normal lapse rate, neither turbulent nor stable, and wind speed was from 6-9 mph at the 8 foot level. Figure 10 shows the drop diameters and numbers per square inch collected on kromekote paper and magnesium oxide coated slides and counted by two different observers. There is no apparent reasonable answer for the difference in drop size data (heavy solid line at top and

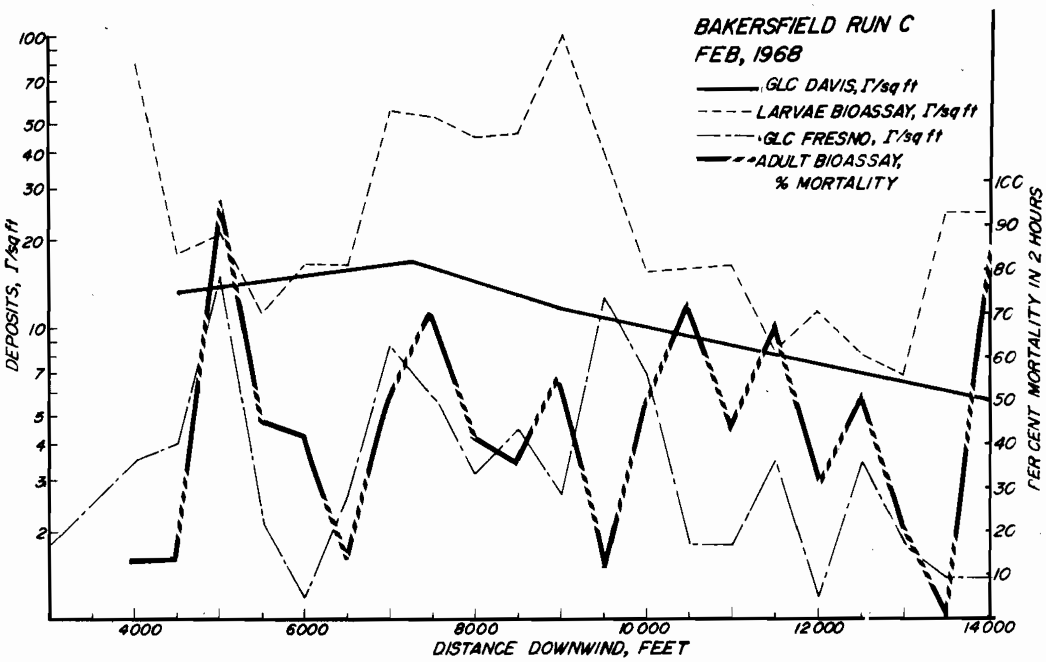


Figure 9. Depositions obtained by gas-liquid chromatography and bioassay, high-altitude wind carried low volume spray tests, Bakersfield.

light dashed line second from top) except for possible calibration differences. As would be expected, the drop size became significantly smaller as the distance downwind increased, but even at 14,000 feet, drops in the 100 to 200 micron size were dominant while nothing smaller than 50 microns appears to have fallen out. The bottom dashed line indicates drop size obtained from the cascade impactors (air samplers) and indicates that very fine particles of 10-30 microns were being carried in the air. Because these are non-evaporative it is expected that they settle out eventually and do not move into the upper atmosphere. However, particles of less than 10 microns vmd will be extremely dependent upon non-turbulent air for settling. The heavy lower-most graph and the jagged dashed-solid graph are for numbers of drops collected. Again, considerable differences were found between observers, but the numbers were sufficient (1-10 drops per square inch) to give reasonable coverage of the flat surface area.

These tests indicated the feasibility of using a low evaporative material with fine atomization for what can be called "drift spraying" of large areas. This technique was further explored in some test runs at Colusa, California, using Dibrom-14, which is effective primarily as an adulticide. Figure 11 shows the results in drop numbers and size range obtained from a test flight using D3-23 cone nozzles (vmd approx. 100 microns) on a tail boom fitted to a Pawnee Air-

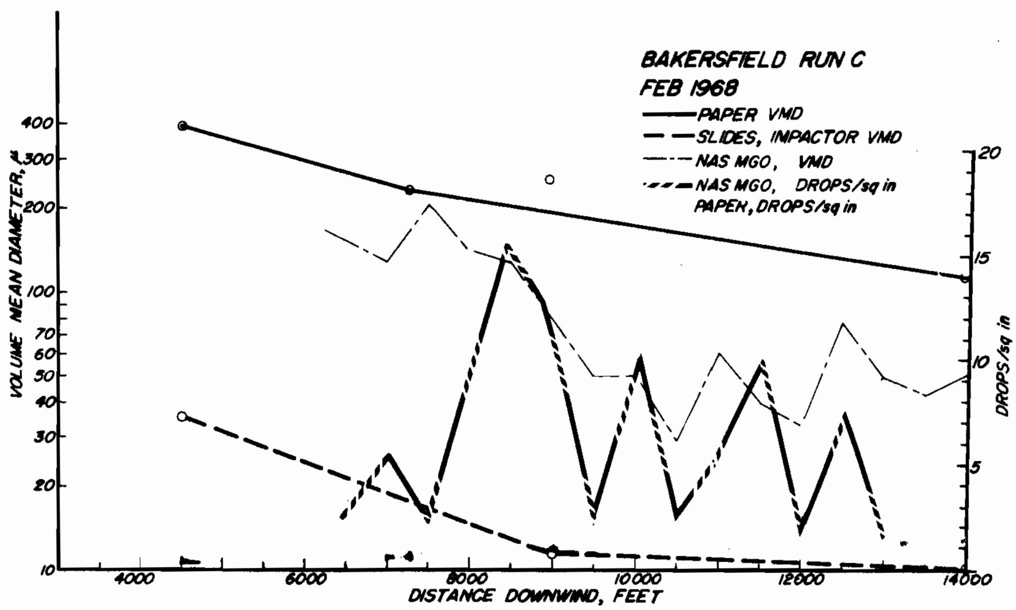


Figure 10. Droplet size and concentration obtained by two methods, high-altitude wind carried low volume spray tests, Bakersfield.

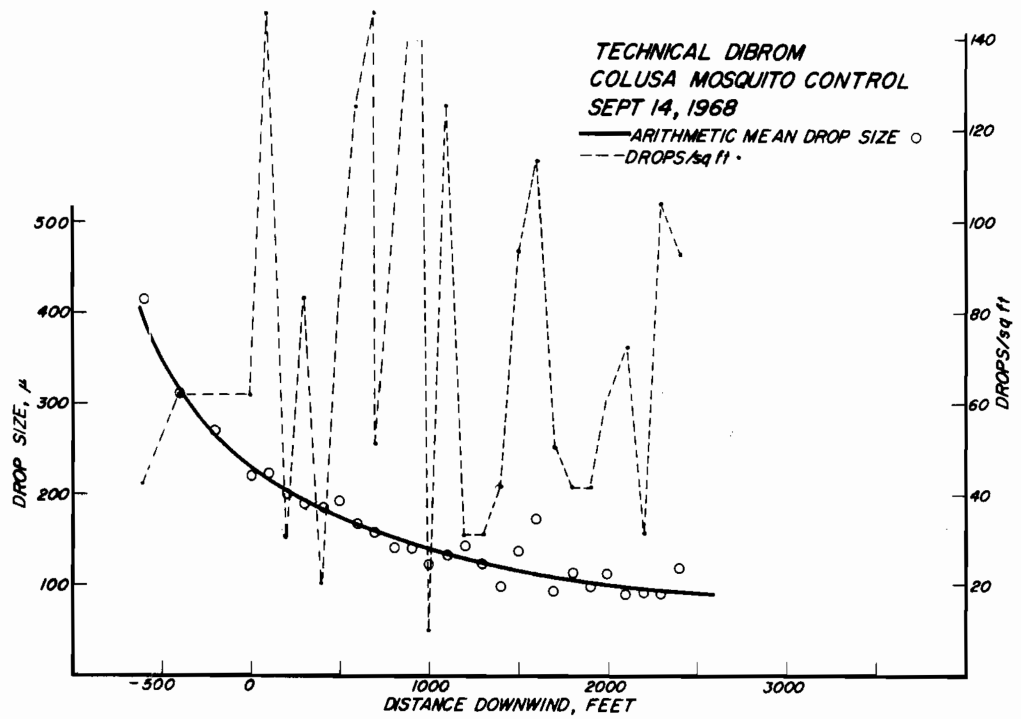


Figure 11. Droplet size and concentration, high-altitude wind carried low volume spray tests, Colusa.

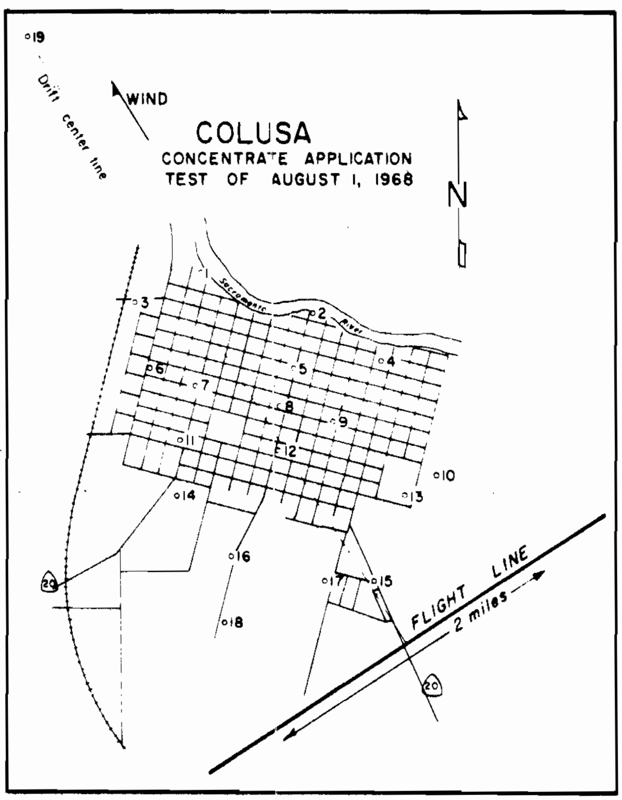


Figure 12. Map of Colusa, California showing location of sampling stations.

craft (Figure 3). The plane was flown at 250 feet altitude in a light and variable wind, and with temperature inversion conditions. The fallout or distribution of spray particles was very effective, even though finer than previous runs, and gave a good pattern out to 2,500 feet. The finer spray produced by the cone nozzles appeared to give satisfactory coverage although well below the number of drops per square inch obtained at Bakersfield.

On September 10, the same aircraft and nozzle system was used in a three altitude test run to try to drift spray across the town of Colusa in successive waves. One pass was made at 500 feet, two passes at 1000, and four passes at 2000 feet altitude. The weather was moderately stable with a near neutral to 0.5 degree temperature inversion condition. Wind velocity at 8 feet was 5 to 6 mph, and air temperature at 8 feet was around 85 degrees F. The sampling station layout was as shown in Figure 12. Each station had caged mosquitoes, Kromekote cards, glass slides, potassium iodide cards and 3 of the stations had air samplers. Figure 13 shows the rather bimodal deposit pattern obtained, which indicates that the deposits from the 500 foot elevation "peaked up" closer than 1000 feet, while the four-times amount released at 2000 feet caused a significant second peak over, and probably beyond the town. The levels in the town (ranging from 200-600 micrograms/square foot) were extremely adequate for caged mosquito control with Dibrom. Figure 14 shows the drop size and frequency distribution for the same run. Here, the three peaks of the frequency graph probably indicate the three altitude levels from which the spray was emitted. The size range drops off with a mixed result which reflects the three release heights. The number of drops per square foot is low but is evidently not too significant with Dibrom. However, it does suggest that still finer atomization and lower flight heights might be in order for better results with Dibrom.

It is quite possible that the use of fine atomization spray technique might be of considerable value to large scale mosquito control problems and emergency situations where towns and fields can be sprayed indiscriminately. Obviously, the cost is much lower in this way, and the annoyance factor of low level spraying over a town is avoided by spraying upwind. Vertical or stacked swaths could be valuable in producing wider more uniformly dispersed coverage. However, it is also obvious that much more care in evaluating weather factors and combining these with drop size data and combining the whole in some type of diffusion model is required before any sort of rational program can be developed. It is impossible at present to predict spray particle sink rates under different atmospheric conditions by a simple Stokes law approach (even if drops are stable in size) without inserting the highly significant factors concerned with eddy diffusion and turbulence of the atmosphere. While the latter can be reduced by spraying under stable conditions (early morning and evening in most places) the first cannot be easily predicted and yet must be fully appreciated in order to make these predictable and successful.

Continued effort on evaluation of safe use of the drift spraying technique will be attempted since need for low cost mosquito control constitutes one of the more urgent problems in California, as well as in many other parts of the world where disease carrying mosquitoes and other insect vectors remain a serious problem to human health.

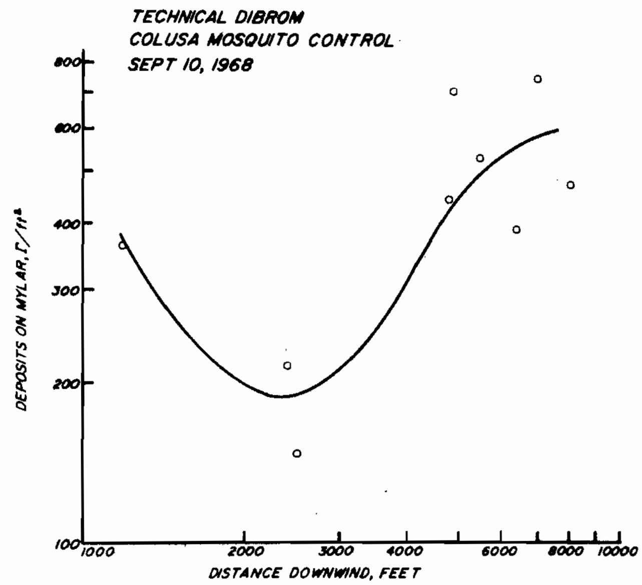


Figure 13. Depositions recovered, high-altitude wind carried low volume spray tests, Colusa.

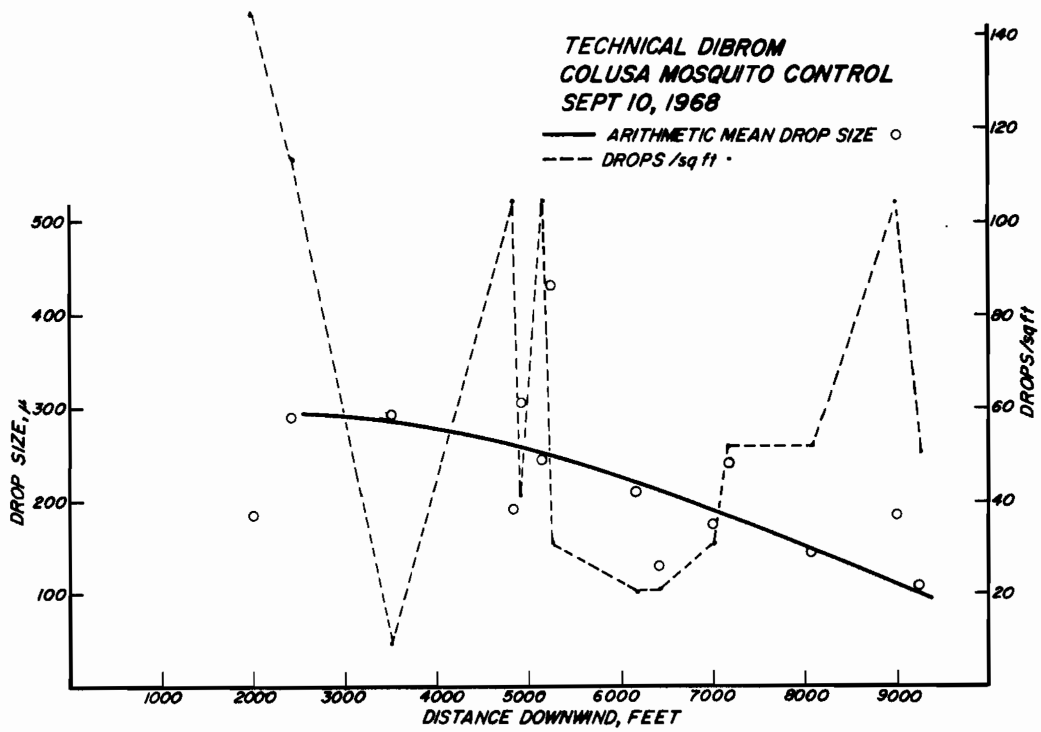


Figure 14. Droplet size and concentrations, high-altitude wind carried low volume spray tests, Colusa.

Graphic data shown in this paper were provided by Captain G.S. Stains and Lt. J.P. Keathley, U.S. Naval Air Station Alameda and by D.J. Womeldorf and Patricia A. Gillies of the Bureau of Vector Control and Solid Waste Management and by Dr. Charles Schaefer of the University of California Fresno Laboratory as well as that from the Agricultural Engineering Department, University of California at Davis.

This Study was supported in part by USDA Contract 12-14-100-8163(33), as well as in part by Public Health Service Research Grant CC 00304 from the National Communicable Disease Center, Atlanta, Georgia.

References Cited

Akesson, N.B. and W.E. Yates. 1964. Problems Relating to Application to Agricultural Chemicals and Resulting Drift Residues. Ann. Review of Entomol. 9:285-318.

Akesson, N.B. and W.E. Burgoyne. 1967. Spray Atomization, Application Volume and Coverage. Proc. Calif. Mosq. Control Assoc. 35:139-144.

Gillies, P.A., D.J. Womeldorf, and J.D. Walsh. 1968. A Bioassay Method for Measuring Mosquito Larvae Depositions. Mosq. News 28(3):415-421.

Linn, Jack D. 1968. Effects of Low Volume Aerial Spraying of Dursban and Fenthion on Fish. Down to Earth 24(2):28-30.

Myers, Charles M., L.L. Lewallen and Benley Nobe. 1968. Residue Studies of Fenthion (Baytex) and Dursban in Central California Pastures. Calif. Vector Views 15(5):51-53.

Winterlin, Wray L., Kenneth Moilanen, and W.E. Burgoyne. 1968. Residues of Dursban Insecticide Following Mosquito Control Applications. Down to Earth 24(2).

Womeldorf, D.J. and P.A. Gillies. 1968. Bioassay Determination of Aircraft Swaths and Rice-Canopy Penetration by Low Volume Insecticidal Sprays at Colusa, California. Down to Earth 24(2):23-27.

Yates, W.E., N.B. Akesson and H.H. Coutts. 1967. Drift Hazards Related to Ultra-Low-Volume and Diluted Sprays Applied by Agricultural Aircraft. Trans. ASAE. 10(5):628-632.

A NEW APPROACH TO MOSQUITO CONTROL IN CEMETERIES

John G. Shanafelt, Jr.

Orange County Mosquito Abatement District, Santa Ana

Mosquito control in cemeteries was recognized as a problem many years before the formation of the Orange County MAD in 1947. Several methods of control had been attempted such as spraying containers, turning containers, metering phenothiazine into the lawn sprinklers, thermal fogging (aerosoling) and mistblowing. Eventually, attempts to place the responsibility for control on the cemetery were investigated by the late Harold Farnsworth Gray, Alameda County Mosquito Abatement District, who found the reason given for noncompliance by cemetery management was that each plot is owned by an individual or family and, under the Mosquito Abatement Act, the legal owner is responsible for preventing a public nuisance on private property. Therefore, cemetery management is not responsible.

Immediately after Orange County MAD operations began in January, 1948, the district manager arranged with the Orange County Planning Department to specify the prevention of mosquito breeding as a condition required for issuance of land use permits.

Twelve cemeteries were in operation in 1947, all under District jurisdiction, with two exceptions; Loma Vista, Fullerton, and Anaheim Cemetery, Anaheim, which were not part of the District. (Table 1)

At the present, eight additional cemeteries are in operation (including one for pets). Incidentally, in 1967, the Anaheim Cemetery became a part of the District upon annexation of the three square mile "old city" of Anaheim.

Originally, the cemeteries were isolated from human habitations, and *Culex quinquefasciatus* Say and *Culiseta incidens* (Thomson) recorded from the containers created no immediate problems since their flight range was short and wild birds and mammals provided them with food.

Early control attempts by the District included thermal fogging two evenings per week; however, the cost of materials and extra man hours needed for each application.

Table 1. Cemetery Statistics, Orange County, 1968.

	Area in Acres	Estimated No. of Containers	% of Mosq. Breeding
*Anaheim Cemetery	12.0	1,000	0%
Ascension Cemetery	45.0	3,250	15%
*El Toro Cemetery	15.0	5,000	13%
*Fairhaven Memorial Park	120.0	28,000	12%
Forest Lawn Memorial Park	160.0	4,400	0%
*Good Shepherd Cemetery	30.0	600	0%
Harbor Rest Memorial Park	40.0	200	1%
Holy Sepulcher Cemetery	80.0	19,900	60%
*Holy Cross Cemetery	3.0	65	0%
*Loma Vista Memorial Park (not in District)	37.0	—	—
*Magnolia Memorial Park	5.0	850	3%
*Melrose Abbey Memorial	20.0	1,000	0%
Memory Garden Memorial	63.0	4,400	0%
Mount Olive Memorial Park (included in Harbor Rest)	—	—	—
*Orange County Dist. No. 1	80.0	21,500	16%
Pacific View Memorial Park	40.0	2,250	0%
*San Juan Capistrano Cem.	5.0	500	0%
*St. John's Lutheran Cem.	20.0	6,000	16%
*Westminster Memorial Park	115.0	10,000	32%
Sea Breeze Pet Cemetery	5.0	25	0%
TOTALS	895.0	108,940	

*Cemeteries in operation prior to August 1947.

plus lack of directional control of the aerosol, caused this method to be abandoned. Hand spraying individual containers was also attempted on one of the smaller cemeteries (Loma Vista). The results were excellent but the operation was performed on Saturdays when the entire staff could be used. Treatment by this method on a large cemetery would have been prohibitive in time and cost.

The use of a Homelite mistblower was attempted in 1950; however, access streets were not laid out with this method of mosquito control in mind. Wind currents created coverage problems. In addition, post-treatment inspections revealed containers within 10-15 feet of the mistblower were adequately treated, those 15-25 feet partially controlled and containers further away were not affected at all. If prevailing winds could not be used to aid in insecticide dispersal, control was limited to those containers within 10-15 feet of the machine.

The influx of people beginning in the early 1950's began the expansion of urban areas and, at the present, many of the cemeteries are surrounded or partially surrounded by new homes and businesses.

Monthly inspections in the spring and fall months, to determine percentage of breeding, mosquito species present and control activity of cemetery personnel, are carried out by the District's Control Foremen. This responsibility is transferred to the District Entomologist's seasonal assistant during the summer months.

Eight cemeteries have averaged 21% of flower containers with larvae. Incidentally, with one exception, these cemeteries were in operation when the District began operating. The remaining ten cemeteries turn all containers upside down when flowers are removed and mosquito production is negligible on these. The need for a practical method of control which could be recommended to the older cemeteries resulted in this study.

The Fairhaven Cemetery, selected for the study site (one of three cemeteries forming a solid block), consists of 55 acres in use at the present. The estimated number of flower containers of the three combined is 65,000. (Fairhaven, 28,000; Orange County District, 21,500; and St. John's Lutheran Cemetery, 6,000) New Subdivisions have encroached on the south and west sides of the "block" and more are planned for development on the north and east.

Fairhaven Cemetery is beautifully landscaped and carefully maintained. Lawn irrigation is by "rainbird" type sprinklers attached to garden hoses and moved manually by the caretakers. The water faucets are also used by visitors for cleaning and filling with clean water for floral arrangements. Mowing, trimming and irrigating are on a weekly cycle, artificial flowers are set aside for mowing, then replaced. Natural flowers are removed if wilted at this time. The containers are usually left "as is"; open to the sky and, of course, are potential mosquito sources. Realizing handling artificial flower arrangements could become a costly maintenance chore, cemetery regulations permit the bouquets to be picked up and destroyed once a week (during mowing cycle); however, this rule is not in force at the present. Arrangement of the individual plots within a single developed area is illustrated by Figure 1.

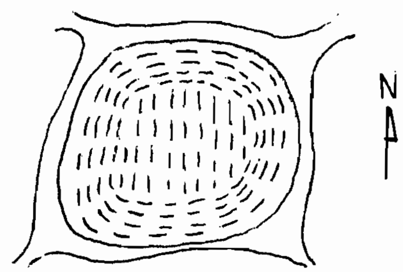


Figure 1. Fairhaven Cemetery grave arrangement 3 or 4 outer rings, center with rows running north and south.

	PRE-TREATMENT RECORDS								POST TREATMENT RECORDS			
INSECTICIDE TESTED	NO. OF GRAVES	NO. OF CONTAINERS	CONTAINER UPSIDE DOWN	DRY	WATER NO MOSQ.	LARVAE PRESENT	ART. FLOWERS	NATURAL FLOWERS	NUMBER OF CONTAINERS WITH LARVAE 24 hrs	36 days	57 days	131 days
CONTROL - AD	72	43	1	11	-	14	0	0	14	3	3	3
DIESEL+ SPREADER	165	115	3	23	64	25	3	0	0	0	0	0
FLIT MLO	168	120	2	38	57	23	0	0	0	1	3	1
.02 BAYTEX-OIL	148	101	4	10	72	15	4	1	0	0	0	0
.05 ABATE-EMUL.	152	84	17	4	45	18	0	0	0	0	0	2
CONTROL - P	99	54	0	8	33	13	0	0	13	14	14	14
2% BAYTEX HR GRAN	123	88	4	20	64	24	9	0	0	0	0	1
1% ABATE GRAN	106	73	1	11	56	5	4	0	0	0	0	0
TOTALS:	1033	678	32	125	391	137	20	1	27	18	20	21

Table 2. Results of field application of liquid and granular insecticides.

Two plots, AD and P (Figure 2), were selected for insecticide applications. Pre-and post treatment inspections were made, using a glass turkey baster. Although such a method can become backbreaking, the inspections were accomplished much faster than by removing container, pouring contents into white enamel pan and examining.

The insecticides used were diesel oil with spreader, Flit® MLO, .02 lb/gal Baytex® in diesel oil, .05 lb/gal ABATE® water emulsion, 2% Baytex HR granules, and 1% ABATE granules. (Table 2)

Applications of liquids and granular insecticides were intended to duplicate District personnel usage. Liquid applications were made with a 2 gallon Hudson garden pressure sprayer with an operating pressure of 60-30 lbs. The average release was 3.4 ml. The hand valve must have a positive action since oil drips can stain headstones and also leave a trail of burned spots or lines on the grass. Timed runs by operators averaged 25 containers per minute.

A plastic "do it yourself" weed killing applicator, "Killer Kane" ($2.00 each from garden supply store), appeared to have been made for individual flower container treatment. This unit consists of a transparent plastic tube, 1¼″ in diameter, 34″ long. At the bottom is a plunger type release valve. Capacity when filled is .47 liter (one pint) and the average release is 2.5 ml, or 200 releases per charge. Under field conditions, applications were identical to the Hudson sprayer, 25 per minute, with the additional advantages of light weight and elimination of pumping. The plastic material of tube and valve were unaffected by Flit MLO or .02 lb/gal Baytex in diesel oil. Since the unit was designed for ground surface application, it is necessary to extend the plunger rod five inches to eliminate a backbending motion by operator and also to assure insecticide release above the water level of container since water and debris will be drawn into the tube through the valve when the unit is lifted from the container if used "as is".

Granules were applied to individual containers through a hornseeder wand (regular disc removed) with a tin funnel soldered to the top end. Granules were dispersed from a cardboard "shaker" tube with the opening set to release 1 cc of granules per shake. Although two hands were necessary to apply the granules, the length of the "wand" eliminated body bending.

Incidentally, the latter two methods of application eliminated the squeezing and releasing hand action necessary to operate a garden type sprayer.

Results

A 24-hour post-treatment inspection revealed 100% kill by each application. Controls remained the same as the pretreatment inspection. This result was anticipated since the individual releases were excessive. Inspection at 48 hours indicated no reinfestation. The first reinfestation was noted 36 days after treatment (Flit MLO test). At the end of 131 days, only 4 containers of 444 treated had been reinfested.

To determine the feasibility of turning containers upside down as a control measure, Area R was selected (Figure 2). A total of 171 graves was surveyed. Of these, 87 (51%) had containers; 6 (7%) were found upside down; 27 (31%) were turned upside down; 50 (57%) were rusted to sleeve and were impossible to turn; 2 (3%) were dry. Fifteen contained mosquito larvae.

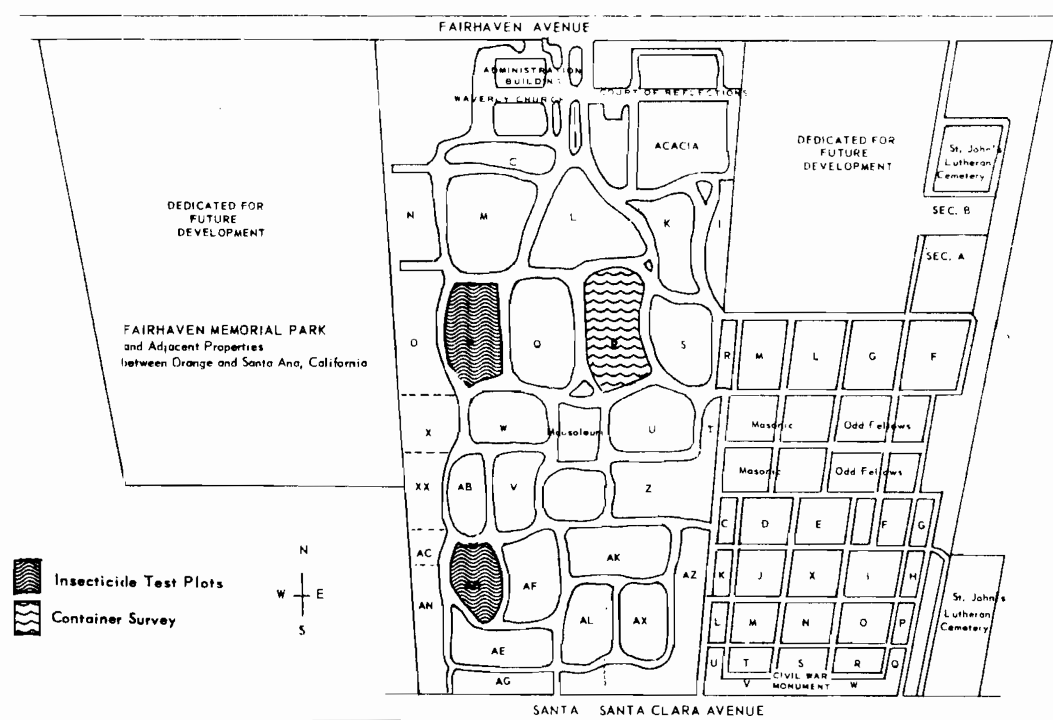


Figure 2. Fairhaven Memorial Park – Site of mosquito source study.

If each container were filled with flowers each Sunday, the gardener's task of removing wilted flowers and turning containers upside down would be a costly operation; however, after several trips to the cemetery, it became apparent that the flowers did not appear to increase or decrease. To follow up this observation, the entire cemetery was surveyed to determine the number and type (artificial or natural) of flowers present on a normal day. The results were quite interesting. A total of 1,392 floral displays were counted and, of these, 1,191 were artificial (indicating only that a visit had been made since artificial flowers became available), 201 natural. Percentage-wise, 5% of all containers were in use, but only .07% of the 78,000 were current natural floral contributions. (Table 3)

Observations of special interest made during the study were:

1. Mosquito breeding appeared to be confined to specific containers – there was not a "normal" dispersal into adjacent water-filled containers. Mosquito breeding (within the untreated controls) appeared to be confined to the same containers at the end of 131 days, containers free of larvae were free of larvae at the end of 131 days.

2. Larvae were most often found in containers located in areas shaded from afternoon sunshine (usually on the east side of shrubs or trees).

3. Failure of treated containers to be reinfested within a reasonable time would again indicate sub-normal dispersal of the mosquitoes.

4. Sleeves present without containers were not a mosquito breeding problem since irrigation water soaked away within three days. Tight soils in other areas might prevent water penetration, hence provide a potential mosquito breeding source.

Conclusions

1. Mosquito control by the hand methods described above would be impractical except within a small cemetery or on an emergency basis.

2. Dosage used in the treated areas produced results; however, evaluations of individual insecticides with each other would be impossible. The interesting point was the indication that 3 to 4 months' control following one such application might be obtained.

3. If a cemetery started with a fresh slate, all containers upside down and a consistant container turning program was undertaken, the tiny extra effort needed to prevent mosquito breeding would be almost unnoticed.

Recommendations

1. A cooperative arrangement between the cemetery and the mosquito abatement district whereby cemetery and district personnel would work together following Easter and Memorial Day activity, removing all flowers and turning containers – suggest also wiring artificial flowers and bending stems so flowers might be placed on the ground but not in containers. Rusted containers should be removed if possible or bottoms punched to permit water to drain out.

2. Retain the sleeves but replace metal containers by providing disposable paper containers available from vending machines.

3. Eliminate all holes in the ground and provide disposable containers adapted for use above ground.

References Cited

Aarons, Theodore. 1948. Cemetery Mosquito Control by Aerosol. Proc. Calif. Mosq. Control Assoc. 16:84-85.

Kelley, Thomas F. 1941. Mosquito Breeding in certain Cemeteries in Alameda County. Proc. Calif. Mosq. Control Assoc. 12: 111-121.

Table 3. Flower distribution at Fairhaven Memorial Park, August 8, 1968. Of 28,000 containers, 4% contained artificial flowers and .7% contained natural flowers.

Area	Artificial Flowers	Natural Flowers
C	8	8
I	0	0
K	13	0
L	56	18
M	197	25
N	49	6
AZ	160	23
RS	4	0
R	6	2
Q	45	17
P	20	0
U	25	5
W	16	2
TZ	158	20
V	5	0
AB	13	2
AK	154	14
AF	41	7
AD	13	4
AX	6	0
AL	96	15
AE	45	9
O	22	9
X	0	0
XX	6	1
AN	14	5
AG	45	6
South	19	3
Total	1,191	201

EVALUATION OF CONCENTRATED INSECTICIDE INJECTIONS AGAINST MOSQUITO LARVAE IN POLLUTED WATER

Don J. Womeldorf[1]; Stephen M. Silveira[2], Grover W. Force[2], Gordon F. Smith[3], and Robert W. Cochran[3]

Introduction

Injection of concentrated insecticide directly into sources of mosquito larvae is currently in its third cycle of popularity in California. The advent of DDT in the late 1940s precipitated evaluation of its potential in a variety of ways, including chemical irrigation in pastures (Geib and Smith 1949, Smith and Geib 1949). The coincident development of DDT resistance in *Aedes nigromaculis* (Smith 1949) discouraged further experimentation. In the next decade, the organophosphorus compounds Phosdrin® (mevinphos), Dipterex® (trichlorfon), and parathion were tested as control agents in chemical irrigation (Gahan and Mulhern 1955, Gahan 1957). Rapid toxicity loss was demonstrated and the technique was never broadly applied. Recently, newer organophosphorus insecticides have received attention as possible control agents in the irrigated-agriculture situation, and are now under investigation (Mulla 1968, Mulla et al. 1969).

Sjogren and Mulla (1968) injected larvicides into polluted-water sources of *Culex* spp, using constant-head aplicators to drip the insecticide into the water for a period of 100 minutes to 24 hours. Control was achieved at economical rates. The sources were generally small (to 17 acres), compared with irrigated agricultural sources which may be of several hundred acres, or were flowing water in ditch situations.

The Turlock and East Side Mosquito Abatement Districts together encompass all of Stanislaus County, at the center of California's Great Central Valley. Both districts abound in sources of *Culex pipiens quinquefasciatus*, ranging from street catch basins and household drains through wastewater associated with cattle and chicken farming to sewage oxidation lagoons of several acres. The usual control practice is to inspect the sources and spray them as needed (generally at weekly intervals) with fenthion at the nominal rate of 0.1 lb/acre. In most instances control is good; however, this procedure requires a disproportionate amount of effort since many sources are accessible only with difficulty and typically harbor weeds and surface scum which protect the larvae.

[1]California Department of Public Health, Bureau of Vector Control and Solid Waste Management, Sacramento.

[2]Turlock Mosquito Abatement District, Turlock.

[3]East Side Mosquito Abatement District, Modesto.

Table 1. Selected tests comparing toxicity of three insecticides to field populations of *Culex pipiens quinquefasciatus*, Stanislaus County, California.[1] Results (ppm) rounded to two significant figures.

Source	Date	Fenthion			ABATE			Dursban		
		LC_{50}	95% Limits	LC_{90}	LC_{50}	95% Limits	LC_{90}	LC_{50}	95% Limits	LC_{90}
catchbasin	18 July 1966	.0035	.0030–.0041	.0066	.00089	.00082–.00096	.0016	.00079	.00072–.00087	.0013
irrigation siphon	18 July 1966	.0030	.0025–.0036	.0078				.00053	.00046–.00059	.00088
dog pound drain	2 Aug. 1967	.0064	.0055–.0075	.011	.0016	.0014–.0019	.0026			
Chicken house drain	15 Aug. 1967	.0080	.0070–.0094	.016				.00078	.00063–.00092	.0016
septic tank drain	17 Aug. 1967	.0034	.0030–.0037	.0062	.00091	.00081–.00099	.0015			

[1]Procedure described by Gillies and Womeldorf (1968).

The two agencies were particularly interested in attempting larval control in this situation by simply pouring insecticide concentrate directly into the source in so-called "slug" doses. This paper summarizes evaluations of several tests utilizing this technique as well as drip applications.

Materials and Methods

The three leading candidate insecticides among those currently available were fenthion, ABATE®[1], and Dursban®[2]. Recent tests comparing the residual effectiveness of the three agree that fenthion persists for the shortest time in water of comparatively high organic content (Lewis et al. 1966, Steelman et al. 1967, Sjogren and Mulla 1968). Toxicity tests on field populations of *C. p. quinquefasciatus* in Stanislaus County consistently show the species to be more tolerant of fenthion than of the other two materials (Table 1). For these reasons, fenthion was tested only once, while ABATE and Dursban were used for most trials. On a few occasions, BITHION®, a preparation containing 6 lb/gal of the same active ingredient as ABATE, was used. For convenience, the name "ABATE" is used in this paper for both formulations. All formulations used formed highly stable suspensions at the dilutions tested.

Sites chosen for observation included several kinds of polluted-water sources. Their water relationships enabled grouping them as flowing water, semi-static water, or static water.

Two ditches represented flowing water sources. The Harding drain receives surplus irrigation water and the effluent from the Turlock sewage treatment plant, transporting it through a total length of 5.5 miles to the San Joaquin River. Following the end of the irrigation season in mid-October only sewage effluent flows in the ditch, at relatively low rates (on the order of 8 million gallons per day). Enormous numbers of mosquito larvae are produced until cold weather causes breeding to cease. Conventional control efforts are complicated by trees, brush and spoil banks along the ditch. A single fenthion treatment was made by drip application in 1967, while four slug applications of ABATE were made in 1968.

The Hunt drain is a ditch system in the Oakdale Irrigation District system which also receives liquid waste from a cannery. During the peak of the tomato canning season, tremendous mosquito production occurs. A dense, thatch-like grass cover along the banks and trailing into the water renders spraying difficult and ineffective. About 25 miles of canal are involved, including branches below the point of cannery waste discharge. Three ABATE treatments were made with a simple dripper during 1968.

[1]Registered trademark, American Cyanamid Co. 0, 0-dimethyl phosphoro=thioate 0, 0-diester with 4, 4-thiodiphenol.

[2]Registered trademark, Dow chemical Co. 0, 0-diethyl 0-(3, 5, 6-trichloro-2-pyridyl) phosphorothioate.

Semi-static waters were sewage treatment ponds which function for oxidation and discharge either through streams or by percolation. Typically, weed growth along the edges of such ponds provides protected larval habitat.

Sewage effluent from the small town of Hughson is percolated from a 2.8 acre pond averaging 3 feet deep. Industrial waste, mainly from a creamery, is discharged into a 3.5 acre pond 3 feet deep with an outlet into the Tuolumne River. The two ponds were treated with ABATE by slug and by drip respectively.

The Waterford sewage treatment plant pond complex is composed of an initial "holding" pond 50 x 570 x 5 feet, followed by a series of four smaller ponds 50 feet wide and 1 foot deep and totaling 700 feet in length. Discharge is through percolation. This complex was treated in its entirety twice with ABATE slugs.

Static water sources were those with large holding capacity in relation to inflow and which had no apparent outflow, losing water almost entirely to the atmosphere by evaporation and transpiration from emergent vegetation. The Scott drain is the overflow from a single-family cesspool. The Schmidt and Brazil drains receive effluent and washwater from large dairy farms, while the Zeering and Hatlen drains receive overflow drinking water, often mixed with manure and waste feed, from laying-hen operations. These were treated with ABATE and Dursban slugs.

Applications by drip were made with a constant-flow dispenser similar to that described by Gahan et al. (1955) or with a simple gravity-flow dispenser constructed by brazing a pipe nipple to a five-gallon can and restricting the flow with a nozzle orifice or a syringe tip and hypodermic needle. Slug applications were made by pouring directly into the source water at the inflow point a predetermined and premeasured amount of emulsifiable concentrate.

Applications in flowing water were to result in a concentration of 0.1 parts per million (ppm) by weight of the flow for a designated time period, based on flow information obtained from the ditch authority. Applications in semi-static and static water were planned to result in a concentration of 0.1 ppm by weight of the volume of water in the pond. This required 1 fl oz of 4 lb/gal emulsifiable concentrate (the weight of both the ABATE 4E and Dursban M formulations used) per 5000 ft^3 source water. Approximate source volumes were established by determining the surface area and muliplying by the average depth of the polluted water, estimated as closely as was practicable. A few treatments were made at higher or slightly lower concentrations.

Field evaluations were made by examining water sampled with a white enameled dipper. Observations were made prior to and after treatment at varying time intervals.

Samples were collected for bioassay in 4-oz waxed paper cups and transported to the laboratory where they were analyzed as described by Gillies et al. (1968), using *C. p. quin-*

quefasciatus larvae from a colony maintained by the University of California mosquito control research laboratory in Fresno.

Results

Treatments in flowing water - In November, 1967, a drip application of 4.2 lb fenthion was made over a 17-hour period to a flow in the Harding drain totaling 36 million lb water, for an average concentration of 0.117 ppm. Counts of immatures ranged to 200 per dip prior to treatment. Excellent kills were obtained of all larval instars, and some pupae were killed. Reinfestation was noted a week after treatment. Bioassays at several points along the ditch showed that the insecticide remained more or less intact as it moved downstream.

In October and November, 1968, four slug applications of ABATE were made. Based on 1967 observations, it was assumed that the slug application would extend to treat water flowing in the ditch over a four-hour period. Stations at which larval observations and water samples were made were spaced one-half to one mile apart. Densities of immatures prior to each treatment ranged to maximums of 50 to 200 per dip.

Treatment amounts and degree of kill are recorded below:

Date	ABATE 4E (ml)	Parts per million (4 hour flow)	Control of immatures
23 Oct.	630	.060	90–100%
28 Oct.	930	.089	100%
31 Oct.	949	.091	100%
12 Nov.	1131	.109	90–100%

In all cases, reinfestation occurred very soon. First instar larvae were noted as early as 29 hours following treatment.

Bioassay results obtained following the November 12 application are listed in Table 2. The sporadic high levels off the main stream of insecticide flow are probably due to an unknown contaminant in the sewage effluent.

Three drip treatments were made at the Hunt drain in September, 1968. Flows at that time remained constant at 53 cubic feet per second. Dosages were calculated to result in average concentrations of 0.1 ppm ABATE during the four hours of application. Larval observations were made at several points throughout the system, the farthest being about 4 miles from the point of injection. Larvae were present in varying densities prior to all treatments.

Following each of the three treatments, larvae were completely absent throughout the canal system at the 24-hour inspection. At 48 hours, first instar larvae were found.

Treatments in semi-static water - Applications were made July 2, 1968, to the Hughson sewage treatment plant to allow observing insecticide dispersal and persistence. No larvae were present at the time of treatment. Seventy-three fl oz ABATE 4E were applied as a slug dose to the inlet of the domestic effluent pond and 128 fl oz ABATE 4E in 5 gal water were dripped into the inlet of the industrial effluent pond over a 4-hour period. Bioassay samples were taken

Table 2. Results of bioassays following ABATE slug treatment of the Harding drain, Stanislaus County, 1968. Initial application 1131 ml ABATE 4E for an assumed concentration of 0.109 ppm based on 4 hours' flow. Bioassay sensitivity 0.005 ppm.

Sampling time treated 0530	Miles from point of injection 0	1/2	1	1-1/2	2	2-1/2	3-1/2	4-1/2	5-1/2
0600	.008								
0700		.03	.26						
0800								.066	
0900	.0055	.0078	.072	.098					
1000				.084	.12				
1100				.016	.06				
1200		.06			.042	.066			
1300						.031			
1400						.0084	.098		
1500						.0054	.066	.03	.0078
1600							.005	.037	
1700						.0058	.031	.044	.0062
1800									.084
1900									.066
2000									.01
2100									.0054

Table 3. Field results: ABATE 4E slug treatments in static water, Stanislaus County, 1968.

Source	Ft^3	Date	no/dip (range)	fl oz	ppm	day larvae: dead	– reappeared[1]	Remarks
Zeering chicken house drain	15,000	10 July	0-30	3	.1	2	19	no breeding day 12; not checked until day 19.
		30 July	2-15	3	.1	1	13	
		14 Aug.	0-15	3	.1	1	21	
		9 Sept.	2-30	3	.1	–	–	checked only days 7 & 14: negative both times.
Zeering A chicken house drain	4,000	10 July	0-100	4	.5	1	–	no breeding day 12, when pond dried.
		14 Aug.	10-30	18	2.25	1	–	no breeding day 100, when observations terminated. Eggs present after day 21.
Schmidt dairy drain	23,000	10 July	0-3	4	.087	1	16	
		30 July	0-10	4	.087	3	13	larvae present day 1; no check day 2.
		14 Aug.	5-30	4	.087	1	13	
		28 Aug.	1-20	4	.087	–	12	no check until day 6; negative then.
		13 Sept.	2-5	4	.087	–	17	a few larvae day 3; not checked again until day 17.
Hatlen chicken house drain	2,500	24 June	many	0.6	.12	–	–	breeding undiminished through 7 days observations.
		9 July	0-50	2	0.4	2	20	no breeding day 13; not checked again until day 20.

[1]Second instar or larger

from six points around the periphery of each pond. The findings are summarized below:

days after treatment	treatment method: slug	drip
½	pond 2/3 covered	pond completely covered
1	pond completely covered	pond completely covered
2	coverage complete, toxicity decreasing	coverage complete, toxicity decreasing
4	coverage complete, toxicity decreasing	coverage complete, toxicity decreasing
7	coverage complete, toxicity decreasing	coverage complete, toxicity decreasing
10	Half of samples showed no activity after 24 hours observation	coverage complete, toxicity decreasing

Treatments at the Waterford sewage treatment plant pond complex were made by pouring 36 fl oz ABATE 4E into the inlet on July 2, 1968, and 32 fl oz BITHION on August 21. Larvae were numerous on both occasions.

After the first treatment, larvae were present until the third day. Re-infestation began on day 8 and was significant on day 13. Bioassay of water samples from the lower one-third of the system never showed insecticide levels above 24-hour sensitivity levels, yet larval control was observed to be good.

Following the second treatment, larval reinfestation was observed on day 21. The interesting observation was made after both treatments that larval development appeared to stop at the third instar for several days.

A single slug treatment was made August 23, 1968, in the Oakdale sewage treatment plant, using 16 fl oz Dursban M. Larvae were plentiful prior to treatment. No post-treatment inspection was made until day 5, at which time all larvae were dead. First reappearance was at day 13, with fourth instars being found on day 19. It should be noted that the first reappearance of larvae was in a very localized area where the inflow appeared to form an eddy, possibly clearing the insecticide from that area.

Treatments in static water - Tables 3 and 4 summarize results of ABATE and Dursban slug treatments. ABATE treatments at about 0.1 ppm prevented reinfestation for 12 to 21 days, except at the small Hatlen chicken house drain. An increased dosage was needed to establish control. A deliberate overdose of 2.25 ppm at the Zeering chicken house drain gave control for 3 months. All Dursban treatments

Table 4. Field results: Dursban M slug treatments in static water, Stanislaus County, 1968.

Source	Ft^3	Date	no/dip (range)	fl oz	ppm	day larvae: dead	– reappeared	
Brazil dairy drain	20,000	19 Aug.	0–30	4	.1	4	–	no breeding on day 95, when observations terminated. Eggs noted after day 21.
Scott cesspool drain	500	19 Aug.	3	1	1.0	1	–	no breeding on day 95, when observations terminated.
Hatlen A chicken house drain	10,000	19 Aug.	20–30	2	.1	1	–	no breeding on day 35, when pond dried
Schmidt dairy drain	23,000	20 Oct.	5	4	.087	3	–	no breeding on day 72, when observations terminated.

approximating 0.1 ppm lasted throughout the periods of observation, from 35 to 95 days. As would be expected, a deliberate overdose of 1 ppm also gave extended control.

Discussion

The field trials demonstrated that operational uses of direct insecticide applications to control mosquito larvae in polluted water are potentially feasible. Using the water of a mosquito larval source as a carrier allows the chemical to be transported into situations nearly inaccessible to conventional sprays. Calculating dosages volumetrically rather than on a surface area basis compensates for the fact that polluted water sources are often relatively deep. The insecticide was observed to move throughout the volume and effect kills at some distance even in water with little or no discernible flow.

Slug treatments were effective in static, semi-static, and flowing water, although drip treatments provided better time and concentration control in flowing water. ABATE treatments at 0.1 ppm in static water can provide adequate control in most instances so that retreatment would be required only at two-week intervals. There are apparently situations where a dosage of 0.1 ppm is insufficient to give control for that length of time. At higher rates, even longer control is possible. Limited observations indicate that Dursban at 0.1 ppm may control larvae for several weeks. In moving water, little or no residual effect was achieved.

One explanation of the long Dursban residual observed in water of high organic content is that the material attaches to solid matter (Wade 1968). It is possible that the insecticide is re-released into the water, although, considering the low amounts found in the water by Wade, it is more likely that the larvae ingest the chemical as they feed on particulates. ABATE may act in the same way, allowing the relatively long control periods observed. Bowman et al. (1968) documented the phenomenon of surface adherence of ABATE.

Results of the tests to date are encouraging enough to warrant limited incorporation of the technique into the operational programs of the two districts, but there are several considerations which must be taken into account. Conditions would be hypothetically ideal for developing resistance in treated populations because of the residual nature of treatments in static water. Thorough inspection is therefore necessary and retreatment at proper intervals is of prime importance. Concentrated insecticide must necessarily be transported and applied in the field; thus, only chemicals with minimal potential hazard should be used. Since concentrations in the treated water exceed the assumed dosage at the site of injection for a length of time, danger to people, livestock, and other nontarget organisms must be avoided. Some nontarget organisms might be endangered by certain chemicals at levels of 0.1 ppm (for example, some species of fish are highly sensitive to Dursban).

It must be noted that response to this type of treatment is varied among sources of the same type. Personnel involved in operational use of this technique must understand the factors involved in selecting the minimum dosage required to obtain control. The operator must become thoroughly acquainted with each source and maintain a complete history of mosquito development and material applied.

Acknowledgments

Dr. Mir S. Mulla, University of California at Riverside, provided advice throughout the study. Mrs. Judy Souza, Turlock Mosquito Abatement District, maintained records and performed the bioassays; and operational personnel of both the East Side and Turlock Districts assisted in conducting the field work.

References Cited

Bowman, M.C., H.R. Ford, C.S. Lofgren, and D.E. Weidhaas. 1968. Residues of ABATE®: analysis in mosquito larvae and larvicide suspensions by flame photometric gas chromatography J. Econ. Entomol. 61(6):1586-1589.

Gahan, J.B. 1957. Further studies with water-soluble insecticides for the control of mosquito larvae in irrigation water. Mosquito News 17(3):198-201.

Gahan, J.B., G.C. Labrecque and C.V. Bowen. 1955. An applicator for adding chemicals to flowing water at uniform rates. Mosquito News 15(3):143-147.

Gahan, J.B., and T.D. Mulhern. 1955. Field studies with water-soluble insecticides for the control of mosquito larvae in California pastures. Mosquito News 15(3):139-143.

Geib, A.F., and G.F. Smith. 1949. A preliminary report on the use of DDT emulsible concentrate by a modified drip method for *Aedes* control. Mosquito News 9(1):10-13.

Gillies, P.A., and D.J. Womeldorf. 1968. Methodology employed in the California mosquito larvicide resistance surveillance program. Calif. Vector Views 15(5):45-50.

Gillies, P.A., D.J. Womeldorf, and J.D. Walsh. 1968. A bioassay method for measuring mosquito larvicide depositions. Mosquito News 28(3):415-421.

Lewis, L.F., D.M. Christenson, and G.W. Eddy. 1966. Results of tests with Dursban® and fenthion for the control of mosquito larvae in log ponds of western Oregon. Mosquito News 26(4):579-580.

Mulla, M.S. 1968. New techniques and measures for mosquito control. Proc. Calif. Mosq. Control Assoc. 36:48-52.

Mulla, M.S., H.A. Darwazeh, A.F. Geib, and E.W. Westlake. 1969. Control of pasture *Aedes* mosquitoes by dripping larvicides into flowing water, with notes on residues in a pasture habitat. J. Econ. Entomol. 62(2):365-370.

Sjogren, R.D., and M.S. Mulla. 1968. Drip application of three organophosphorus insecticides for mosquito control. Mosquito News 28(2):172-177.

Smith, G.F. 1949. Kern MAD has circumstantial evidence on DDT resistance. Mosquito Buzz 3(8):2.

Smith, G.F., and A.F. Geib. 1949. Control of *Aedes* mosquitoes by direct introduction of DDT into irrigation water. J. Econ. Entomol. 42(5):835-836.

Steelman, C.D., J.M. Gassie, and B.R. Craven. 1967. Laboratory and field studies on mosquito control in waste disposal lagoons in Louisiana. Mosquito News 27(1):57-59.

Wade, L.L. 1968. The efficacy and stability of Dursban® insecticide in dipping vats for control of the southern cattle tick. J. Econ. Entomol. 61(4):908-909.

FIELD TESTS OF ABATE® AND PARATHION GRANULES IN CATCH BASINS

Charles M. Myers[1], Patricia A. Gillies[1], and Richard F. Frolli[2]

Twenty-four street-draining catch basins were treated for 13 weeks in Hanford, California, in an attempt to control *Culex pipiens quinquefasciatus* Say. Treatments were with 1% ABATE® granules and 2% parathion granules at a dosage of 1 ppm. It was necessary to treat at weekly intervals to maintain control. No significant residual buildup of insecticide beyond one day was obtained as indicated by larval bioassay and reinfestation data.

Introduction

The common house mosquito, *Culex pipiens quinquefasciatus*, has not been incriminated as an important disease vector species in California. It is, however, a major source of urban complaints in many California communities. Probably the most significant recurring urban source of this mosquito is in street-draining catch basins.

Treatments of catch basins vary from district to district. Generally, the basins are inspected early in the mosquito season and the treatment program is instituted when significant breeding is found. Treatment is then usually scheduled routinely without inspection on weekly or longer intervals.

Insecticides, either as emulsifiable concentrates or granular formulations or oils, are the materials in most common use in California. The purpose of this study was to compare the effectiveness of a 1% ABATE Celatom granule with that of a 2% parathion sand core granule.

Methods and Materials

The area treated included the drainage from four drainage systems within an approximately 10 square block area. Twenty-four catch basins were studied. Drain water in the residential area was almost entirely from lawn and garden run-off.

The basins are round with vertical concrete sides. The bottoms are open and the tops are fitted with removable iron lids for cleaning. All basins, with one exception, are 16 inches in diameter and between 24 and 36 inches deep. One basin is 20 inches wide and 39 inches deep. Volumes were determined and accumulated debris was removed from all basins prior to the study period. The catch basins tended to remain either full or nearly so throughout the study, owing to the magnitude of lawn irrigation. Water entered the basins from either the gutters alone or from the gutters and the bottom of the catch basin above it by means of a pipe connecting the bottoms of the basins.

Data presented here were obtained over a 13 week period from May 8 to July 31, 1968. The basins were treated on Wednesdays. At this time, observations were made on water temperature, breeding, and flooding. Water samples were also taken for bioassay if breeding was not present.

On Thursdays, observations were limited to effectiveness of the prior treatment and flooding. Water samples for bioassay were taken from basins treated on Wednesday.

Water samples from all basins were bioassayed for insecticidal activity both before and after treatment if larvae were not present. Samples were transported to the laboratory, refrigerated, and tested as soon as practicable. Twenty fourth instar *C. p. quinquefasciatus* larvae from a susceptible strain were placed in each water sample and the mortality was observed at roughly 1, 2, 4, 8, and 24-hour intervals.

All basins were treated at the rate of 1 ppm insecticide based on the volume of a full basin. Treatments and all other observations were made in the mid-morning.

Two treatment schedules were used during the study. In an attempt to determine residual activity, one series of basins was treated only if breeding was present. A second series of basins was treated weekly, regardless of breeding.

Insecticidal activity was rated as ++ if the KT 50 (Time required to kill 50% of the larvae) was $<$ 2 hours, + if the KT

[1]California State Health Department, Bureau of Vector Control and Solid Waste Management, Fresno.

[2]Kings Mosquito Abatement District, Hanford.

50 was 〉 2 hours but 〈 24 hours, and 0 if the KT 50 was not reached in 24 hours. A KT 50 of 〈 2 hours (++) was considered an effective control dosage. This dosage was determined to be equivalent to .0035 ppm or greater.

Table 1. Bioassay data from catch basins treated weekly with ABATE® 1% or parathion 2% granules.

	ABATE 1%		Parathion 2%	
	Total	%	Total	%
Day 1				
++	60	41	4	10
+	79	53	21	50
0	8	6	17	40
Total	147	100	42	100
Day 7				
++	2	1	1	3
+	51	35	3	10
0	94	64	29	87
Total	147	100	33	100

++ KT 50 〈 2 hours = 〉 .0035 ppm
+ KT 50 〉 2 hours
0 KT 50 〉 24 hours

Results

The average water temperature for all basins for a 7 week period from May 29 to July 10, 1968 was 86°F. The highest temperature reading during this period was 106°F, and the lowest was 70°F. Individual temperature readings were usually quite variable during periods when the basins were being flooded by street drainage.

ABATE 1% granules were applied 147 times. Of these, 94% showed activity by bioassay after 1 day with 41% showing an effective dosage. After 7 days, 36% showed activity by bioassay but only 1% had an effective residual. No correlation between temperature and activity was noted.

Parathion 2% granules were applied 42 times in the 13 week period. Of these, 60% showed activity after 1 day, with 10% having an effective residual. After 7 days, 13% showed activity by bioassay but only 3% had an effective residual (Table 1).

In only one instance were pupae found on the seventh day after treatment with 1% ABATE. Pupae were found on 4 occasions 7 days following treatment with 2% parathion granules (Table 2).

During the 13 week study period, breeding was found 135 times in the 24 basins in the study for an average of slightly more than 10 (43%) of the basins breeding per week. This incidence was regardless of treatments, since the majority of breeding was confined to less than 1/3 of the basins, and no reduction in breeding frequency was evidenced with once-a-week treatment. There was no evidence to suggest a residual buildup of insecticide in the basins as the study progressed. Neither the breeding data nor the bioassay data indicated any residual action beyond 7 days regardless of whether the basins were treated weekly or only as needed. This is not too surprising considering the frequency at which flushing occurred in many of the basins.

Conclusions

Under the conditions of this test, it appeared that street-draining catch basins, of the type described, should be treated at weekly intervals. Considering the large proportion of basins which bred mosquitoes weekly, there seemed to be little value in inspection prior to treatment. A dosage of 1 ppm was sufficient to kill all larvae in the basins at the time of treatment, but no effective residual lasted much more

Table 2. Life stages of *C. p. quinquefasciatus* in catch basins 7 days after treatment.

1% ABATE GRANULES AS NEEDED

Week	1	2	3	4	11	12	13	Total	%
1	6	1	2	4	2	2	4	21	44
2	3	2	3	1	1		2	12	25
3	2	2	3	1		1		9	19
4		2	1	2				5	10
P			1					1	2
								48	100

2% PARATHION GRANULES AS NEEDED

Week	1	2	3	4	11	12	13	Total	%
1		1	1	2				4	15
2		2	3	2				7	25
3		2	4	2				8	28
4		2	4	2				8	28
P			1					1	4
								28	100

1% ABATE GRANULES WEEKLY

Week	5	6	7	8	9	10	Total	%
1	3	1	1		2		7	30
2	1	3	1	1		1	7	30
3	3	1				1	5	22
4	1	1	2				4	18
P							0	0
							23	100

2%PARATHION GRANULES WEEKLY

Week	5	6	7	8	9	10	Total	%
1	1	4	2	2	1	2	12	21
2	2	4	1	2	3	2	14	25
3	2	4	1	2	3	2	14	25
4	2	4	2	1	2	2	13	23
P		2			1		3	6
							56	100

than 24 hours, as evidenced by the breeding data.

Acknowledgements

The authors wish to thank Mr. Genaro Garibay, Kings Mosquito Abatement District, and Mr. Arthur O. Jensen, American Cyanamid Company, for their cooperation throughout the study.

DEVELOPMENT OF ORGANOPHOSPHORUS RESISTANT *AEDES NIGROMACULIS* (LUDLOW) IN THE TULARE MOSQUITO ABATEMENT DISTRICT

Dennis Ramke

Tulare Mosquito Abatement District, Tulare

The Tulare Mosquito Abatement District has depended primarily on the use of organophosphorus compounds to control the pasture mosquito, *Aedes nigromaculis* (Ludlow), since 1952 when parathion was substituted for chlorinated hydrocarbon insecticide. This material was used successfully until 1958, when the first signs of resistance developed (Lewallen and Nicholson, 1959). However, the control program remained relatively successful until the year 1961, when the complete failure of ethyl parathion occurred. Methyl parathion was substituted and used successfully on both larval and adult stages until the year 1963, (Brown et al., 1963) at which time resistance developed again, ending the utility of the most economical insecticides used by the District. A brief history of larvicide failures in the Tulare MAD is given in Table 1.

With the failure of parathion a new organophosphorus compound, fenthion, was substituted. This material was used successfully until early August, 1968, when a serious resistance problem developed in a small pasture complex southwest of the city of Tulare. A routine aircraft application of fenthion applied at 0.1 lb/acre failed to control both larval and adult stages of the pasture mosquito, *A. nigromaculis.* Experimental applications of fenthion applied at 0.2 lb/acre failed to control adult emergence. By the end of October the control problem had spread over a confined area of approximately 3,000 acres of irrigated pasture and alfalfa along the western border of the Tulare District.

Numerous other chemicals have been field tested by personnel from the Bureau of Vector Control and Solid Waste Management at Fresno, and the University of California mosquito control research laboratory at Fresno. These chemicals have been proved ineffective in controlling larvae of the pasture mosquito, *A. nigromaculis.* The lack of replacement larvicides precipitated the search for an effective adulticide. Only Baygon® and dichlorvos (DDVP) were found to be effective against these highly resistant mosquitoes. A list of materials applied as larvicides and adulticides is given in Table 2. All materials were applied by aircraft.

Field and laboratory tests conducted in the affected area confirm high organophosphorus resistance existing in populations of the field mosquito *A. nigromaculis.*

Although not confirmed by operational failures in the field, laboratory tests show levels of fenthion tolerance over the entire District. It is apparently just a matter of time until the whole District is affected.

Table 1. History of insecticide failures against *Aedes nigromaculis* larvae in the Tulare Mosquito Abatement District.

Material	Dosage (lb/acre)	Year of Initial Failure
Parathion	0.1	1958
Methyl parathion	0.1	1961
Malathion	0.5	1965
Fenthion	0.1	1968
ABATE®*	0.05	1965
Malathion/ABATE®*	0.3/0.05	1965
EPN*	0.1	1966
Dursban®*	0.05	1967
Fenthion*	0.2	1968

*Not used operationally, failure based on field trials.

Table 2. Materials evaluated against OP-resistant *Aedes nigromaculis* in the Tulare Mosquito Abatement District during 1968.

Material	Highest ineffective field dosage (lb/acre)	Minimum effective dosage (lb/acre)
Larvicide:		
Methyl parathion	0.1	---
Fenthion	0.2	---
Dursban®	0.05	---
Adulticide:		
Methyl parathion	0.1	---
Fenthion	0.2	---
Naled (dibrom)	0.1	---
Dursban®	0.1	---
Dichlorvos (DDVP)	--	0.1
Baygon®	--	0.05

References Cited

Brown, A.W.A., L.L. Lewallen, and P.A. Gillies. 1963. Organophosphorus resistance in *Aedes nigromaculis* in California. Mosq. News 23:341-345.

Lewallen, Lawrence L. and Loren M. Nicholson. 1959. Parathion resistant *Aedes nigromaculis* in California. Mosq. News 19(1): 12-14.

ORGANOPHOSPHORUS RESISTANCE LEVELS IN ADULTS AND LARVAE OF THE PASTURE MOSQUITO, *AEDES NIGROMACULIS* (LUDLOW) IN THE SAN JOAQUIN VALLEY OF CALIFORNIA

W.H. Wilder and C.H. Schaefer

Mosquito Control Research Laboratory
University of California, Fresno

While mosquito control in California is based primarily on larviciding, control of adults is also necessary to combat migrant populations and when larvicide treatments have failed. Information on the resistance of an adult population having a known larval resistance level would aid in predicting the usefulness of a given compound for adulticiding when that compound did not achieve larval control.

Georghiou et al. (1966) selected larvae of *Culex pipiens fatigans* Wiedemann with the carbamate Baygon® and, in thirty-five generations of selection, the larval tolerance increased twenty-fivefold and the adult tolerance (based on contact testing methods) only threefold; selection of adults for twenty-four generations resulted in a fivefold increase in their tolerance, but there was only a two and one-halffold increase for the respective larvae.

The pasture mosquito, *Aedes nigromaculis* (Ludlow) is intensely pressured via larviciding programs, and larvae have become highly resistant to many organophosphorus insecticides (Womeldorf et al., 1968); however, no published information is available on the toxicity of the most commonly-used organophosphorus insecticides to adults of this species or on the degree of adult resistance in field populations. This paper presents information on the toxicity of Dursban®, fenthion and parathion to adult and larval stages of *A. nigromaculis* from susceptible and resistant areas of the San Joaquin Valley. While this work was in progress, severe control difficulties developed within the Tulare Mosquito Abatement District (Ramke et al., 1969; Schaefer, 1969). Data were obtained on the resistance levels of adults and larvae which resisted control attempts with numerous insecticides.

Larvae were tested by adding acetone solutions of the test insecticide to dixie cups containing 20 fourth instar larvae in 100 ml of water. A graded series of duplicated dosages were run for each test. After 24 hrs at 70°F the percent mortality was determined. Adults were tested by the filter paper exposure method of Georghiou and Metcalf (1961); groups of 20 adults each were exposed to filter papers which had been treated with acetone solutions of insecti-

Table 1. Summary of 1968 tests on larvae and adults of susceptible *Aedes nigromaculis* populations.

	Adults-LC_{50} (% soln.)[1]			Larvae-LC_{50} (ppm)		
Pasture	Parathion	Dursban®	Fenthion	Parathion	Dursban®	Fenthion
Gilbert[2]						
5–2–68	.017	.0034	---	.0045	.0009	---
5–20–68	---	---	---	.0038	---	---
5–27–68	---	---	---	.0042	---	---
5–31–68	.020	.0035	---	---	---	---
7–8–68	.016	---	.0060	.0030	.0006	.0013
Livingston[2]						
7–3–68	.020	---	---	.0054	---	---
North Livingston[2]						
8–19–68	.020	.0030	.0060	.0037	.0007	.0015
8–22–68	.040	.0037	.0140	.0035	---	---
Tarabini[3]						
7–10–68	---	---	---	.0026	.0007	.0013
7–10–68	---	---	---	.0029	.0007	.0013
7–26–68	---	---	---	.0032	---	.0016
West Tarabini[3]						
8–19–68	.007	.0020	.0037	---	---	---
8–29–68	.009	---	.0043	.0017	.0006	.0010
Morsehead[3]						
8–1–68	---	---	---	.0034	---	---
9–9–68	.0075	---	---	---	---	---
AVERAGE	**.017**	**.0031**	**.0068**	**.0035**	**.0007**	**.0013**

[1]Concentration of insecticide solution applied to filter paper.
[2]Porterville area.
[3]Eastern Madera County

Table 2. Summary of 1968 tests on larvae and adults of organophosphorus resistant *Aedes nigromaculis* populations.

Pasture	Adults-LC_{50} (% soln.)[1] Parathion	Dursban®	Fenthion	Larvae–LC_{50} (ppm) Parathion	Dursban®	Fenthion
Susceptible Average[2]	**.017**	**.0031**	**.0068**	**.0035**	**.0007**	**.0013**
Soults[4]						
8–5–68	10.0	.018	.27	.50	.0047	.015
resistance[3]	588X	5.8X	39.7X	143X	6.7X	11.5X
9–6–68	20.0	.018	.20	1.0	.010	.022
resistance	1180X	5.8X	29.4X	288X	14.3X	17.0X
10–3–68	24.0	.023	.21	.40	.006	.016
resistance	1410X	7.4X	30.9X	115X	8.6X	12.3X
Hahsey[5]						
5–21–68	.22	.011	---	.17	.0034	.0090
resistance	12.9X	3.5X	---	48.5X	4.8X	6.9X
9–4–68	6.0	.014	.16	.25	.004	.0094
resistance	354X	4.6X	23.5X	71.3X	5.7X	7.2X
McClure[5]						
8–6–68	2.0	.012	.12	.20	.0045	.0095
resistance	117X	3.9X	17.6X	57.0X	6.4X	7.3X
8–28–68	6.0	.0075	.07	.30	.0058	.0110
resistance	353X	2.4X	10.3X	86.5X	8.3X	8.4X
Loboa[5]						
7–9–68	.58	---	.037	.32	.0040	.0110
resistance	34.0X	---	5.4X	92.2X	5.7X	8.4X
7–11–68	.52	---	.043	.10	.0034	.0077
resistance	30.5X	---	6.3X	28.8X	4.9X	5.9X
Costa[5]						
8–2–68	.90	---	.060	---	---	.0110
resistance	53.0X	---	8.8X	---	---	8.4X

[1]Concentration of insecticide solution applied to filter paper.
[2]See Table 1.
[3]The number of times resistant as compared to susceptible populations.
[4]Western Tulare County, Tulare, MAD.
[5]Eastern Kings County, Kings MAD.

cides. Adults were exposed for a one-hour period and then transferred into untreated containers and held at 60°F until the 24 hour mortality counts were made. Each adult test was conducted at several concentrations, each in duplicate. The percent mortality data was plotted versus concentration on log-probit paper and the LC_{50} and LC_{90} values were read from the lines. In some cases populations were so highly resistant to parathion that LC_{90} values could not be obtained.

The LC_{50} values for larvae and adults of the susceptible populations are shown in Table 1. The averages of these LC_{50}'s are slightly high due to the presence of a low level of parathion resistance in the samples from the uncontrolled Porterville area (Gilbert and Livingston pastures); it is apparent that this area should no longer be used to determine the susceptible baselines. There is no evidence that insecticide tolerance of the susceptible strains change during the season; thus, late season control difficulties do not appear to be related to seasonal changes in the "normal" populations.

The data for resistant populations from the Tulare and Kings MAD's are shown in Table 2 and are compared to the average susceptible LC_{50}'s from Table 1. The adult mosquito data for a given date (Table 2) are a result of tests on adults reared in the laboratory from field-collected larvae for which LC_{50} values are also shown. The resistance levels of larvae and adults cannot be compared directly, since the testing methods for these two stages were quite different; however, direct comparisons between the susceptible and resistant strains of either stage appear sound. A comparison of the response of larvae and adults, of representative susceptible and resistant populations to insecticide concentrations is shown in Figures 1 and 2.

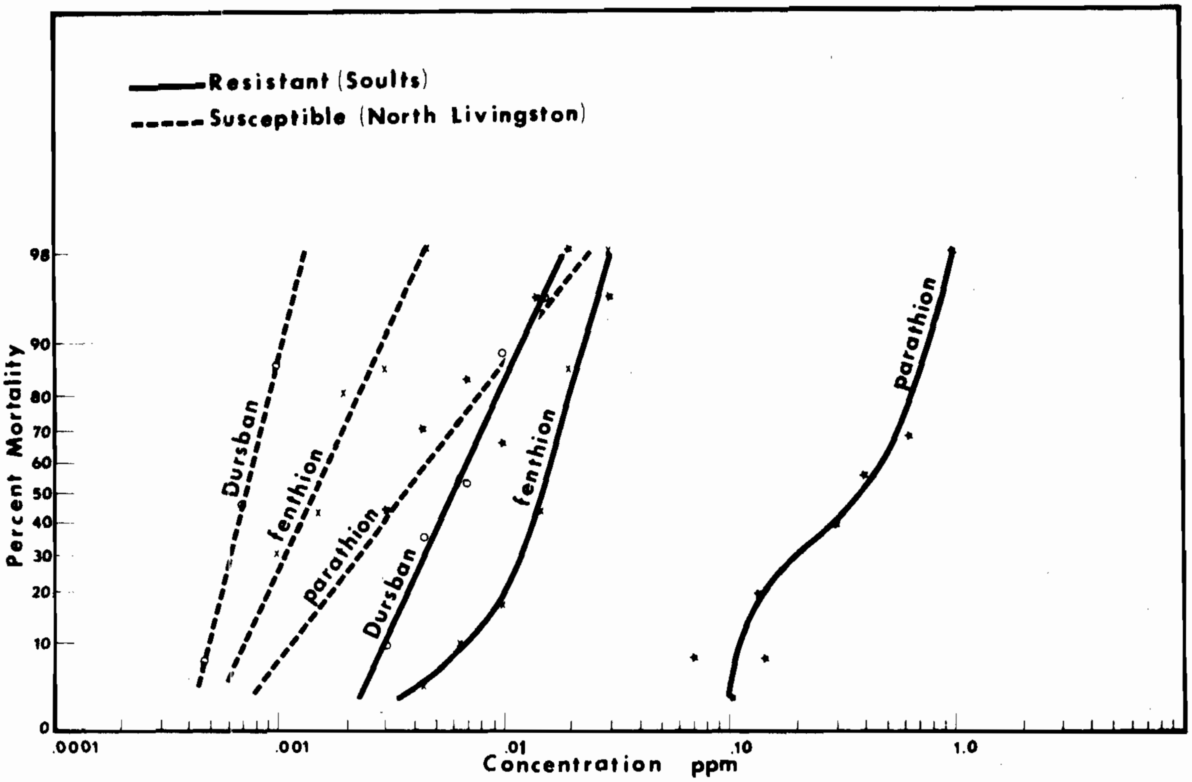


FIGURE 1. Log concentration-probit lines for susceptible (North Livingston) and resistant (Soults) Aedes nigromaculis larvae.

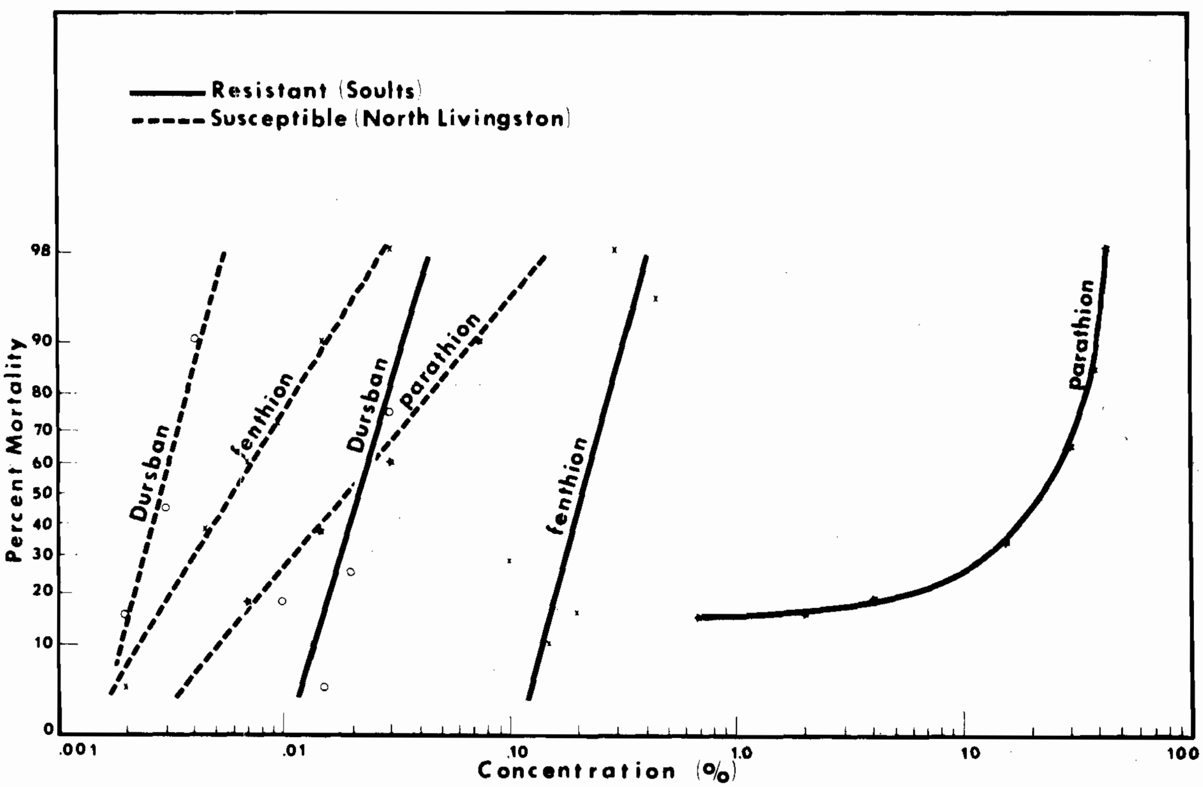


FIGURE 2. Log concentration-probit lines for susceptible (North Livingston) and resistant (Soults) Aedes nigromaculis adults.

Unfortunately, tests were not conducted on any given field throughout the entire season; however, in general, the data indicated a trend toward increasingly higher adult resistance levels as the control season progressed. The two tests for the Hahsey pasture were conducted over three months apart and, while the increase in larval resistance to parathion was less than onefold, adult resistance increased over twenty-fivefold. The resistance levels at Soults' pasture are very interesting, since in September and October field applications of 0.2 lb/acre of fenthion did not achieve control of larvae or adults; parathion has not been useful in this area for several years (Ramke et al., 1969). The cross-tolerance of O-P-resistant *A. nigromaculis* larvae to Dursban has previously been reported (Gillies et al., 1968). The present results show levels of adult resistance to Dursban up to sevenfold (Table 2); although this is much lower than the resistance levels for parathion and fenthion, 0.1 lb/acre of Dursban did not control some adult populations within the Tulare MAD in field tests conducted during September 1968 (Ramke et al., 1969). The magnitude of adult resistance found in these tests was surprisingly high, but yet is consistent with difficulties in controlling the same populations with the same insecticides.

It seems likely that the apparent late season increases in mosquito resistance levels were the result of the insecticide selection which occurred in the preceding months. Many MAD managers have observed that chemical control of *A. nigromaculis* became more difficult in the late part of the season, but, in the early part of the next season, control was easier to achieve. It is possible that late season dispersal of this species is sufficient so that many of the overwintering eggs in a given area, which had harbored highly resistant populations, were laid by females which had moved there from areas where resistance was less. If this were to occur, the next spring population would be heterogeneous with respect to resistance and the resistant members would again be "selected-for" during the season. The high degree of dispersal of late season populations of *A. nigromaculis* is frequently mentioned by mosquito control personnel and was observed in the highly resistant area in the Tulare MAD during October of 1968; for example, one 90-acre field was sprayed for adults at 10 a.m. when the adult count was 15 per leg, by late afternoon there were still 1-2 adults per leg, and, by the next morning 25 adults per leg were present! During this same month many large adult populations were encountered in alfalfa and sorghum fields and even in dry, native pastures. The source of these adults is unknown; however, it is known that *A. nigromaculis* adults can move 20-30 miles and probably much further (Smith et al., 1956).

Other factors also are involved with late-season control problems. As the season progresses, the rate of water penetration decreases, producing more numerous and larger bodies of standing water and an increase in mosquito production (Husbands, 1954). Thus, if larger populations develop and the percent control remains constant, the number of emerging adults may greatly increase. Also, as the season progresses, water depth may increase and flood eggs that were laid on the higher parts of the border ridges; these eggs may accumulate in large numbers from previous broods and, if hatching and developmental conditions are favorable, a serious outbreak may result (Husbands, 1955).

During 1969, further studies will be made to follow given fields throughout the season in order to examine seasonal changes in resistance of the larval and adult stages of given populations.

References Cited

Georghiou, G.P., R.L. Metcalf, and F.E. Gidden. 1966. Carbamate resistance in mosquitoes; selection of *Culex fatigans* Wiedemann for resistance to Baygon. Bull. World Health Organ. 35:691-708.

Georghiou, G.P., and R.L. Metcalf. 1961. A bioassay method and results of laboratory evaluation of insecticides against adult mosquitoes. Mosq. News 21:328-337.

Gillies, P.A., D.J. Womeldorf, and K.E. White. 1968. Cross-tolerance of California *Aedes nigromaculis* (Ludlow) larvae to EPN, ABATE® and Dursban®. Proc. Calif. Mosq. Control Assoc. 36:85. (Abstr.)

Husbands, R.C. 1953. Mosquito ecology studies in irrigated pastures - progress report 1953. Proc. Calif. Mosq. Control Assoc. 22: 43-50.

Husbands, R.C. 1955. Irrigated pasture study -- a review of factors influencing mosquito production -- weather, ponding and irrigation, and soil moisture. Proc. Calif. Mosq. Control Assoc. 23:112-117.

Ramke, D.J., P.A. Gillies, and C.H. Schaefer. 1969. *Aedes nigromaculis* control crisis in the Southern San Joaquin Valley. Calif. Vector Views. 16(2):19-20.

Schaefer, C.H. 1969. Pasture mosquito resistance in California. Pest Control 37:36-37.

Smith, G.F., A.F. Geib, and L.W. Issak. 1956. Investigations of a recurrent flight pattern of flood water *Aedes* mosquitoes in Kern County, Calif. Mosq. News 16:251-256.

Womeldorf, D.J., P.A. Gillies, and K.E. White. 1968. Present status of insecticide resistance in California mosquito larvae. Proc. Calif. Mosq. Control Assoc. 36:81-84.

THE EFFECTS OF WATER QUALITY, TEMPERATURE AND LIGHT ON THE STABILITY OF ORGANOPHOSPHORUS LARVICIDES USED FOR MOSQUITO CONTROL

Charles H. Schaefer and Emil Dupras, Jr.

Mosquito Control Research Laboratory
University of California, Fresno

During the past years, the California Mosquito Control Association Research Committee has recommended that research be conducted on the possible effects of alkaline pasture water on the stability of mosquito larvicides. This recommendation stems from the history of difficulties in controlling the pasture mosquito, *Aedes nigromaculis* (Ludlow) in Tulare and Kings counties; these difficulties were first encountered and have remained most severe in alkaline soil areas. Thus, it was postulated that some factor(s) in the alkaline water was responsible for control difficulties, possibly by reducing insecticide concentration.

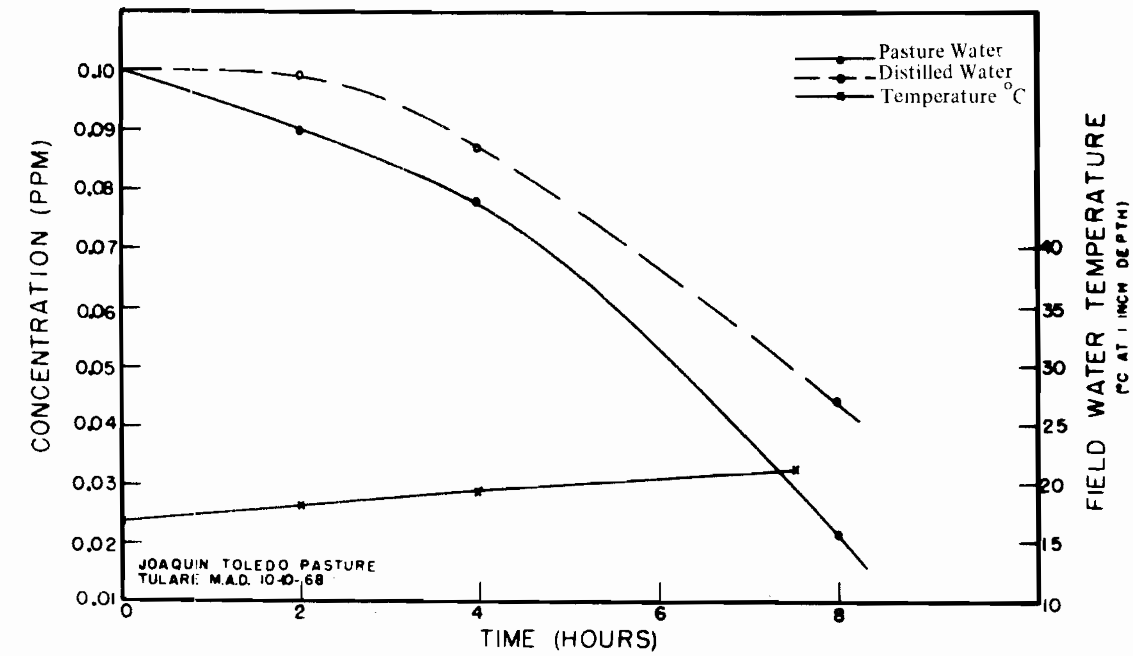


FIGURE I STABILITY OF FENTHION IN PASTURE AND DISTILLED WATER UNDER FIELD CONDITIONS.

Furthermore, the frequently mentioned observation that it is more difficult to achieve control in the late part of the season (September-October) than in the early season (May-July) might also be explained by the gradual increase of some factor in the alkaline water that degrades larvicides.

An overall study of factors which affect the stability of the insecticides used in California mosquito control was initiated at the Fresno Laboratory in 1968 (Schaefer, 1968). This paper presents the results of tests conducted during the past year on the effects of water quality, temperature and light on the stability of organophosphorus larvicides.

Methods

Pastures having a history of mosquito control difficulty in the alkaline soil areas of Kings and Tulare counties were selected for these studies. Three organophosphorus compounds, which are well-known larvicides, were chosen as the test insecticides: parathion was selected as it had once been the main larvicide used in these areas, fenthion because it was in common use at the time of this study and Dursban® because it is expected to come into common use. An initial concentration of 0.1 ppm was selected, since one would expect to encounter this level in pasture water following applications of 0.1 lb per acre of active insecticide - a common application rate for these larvicides.

As a basis of comparison, all tests on the stability of these larvicides in pasture water were simultaneously conducted in distilled water; thus, the stability can be compared between "pure" and pasture water held under the same conditions and at the same time. Each insecticide was tested twice under field and twice under laboratory conditions, and all treatments were run in duplicate in each test.

Field Tests - Pasture water was collected from a given field when third or fourth instar *A. nigromaculis* larvae were present. Thus, the pasture water samples were truly representative of a breeding site at the time when spray treatments would normally have been made. For each test, about three gallons of pasture water were collected and filtered through a plug of coarse glass wool; this removed larvae and large pieces of organic matter but did not eliminate fine suspended organic matter. The yellow color of the pasture water was unchanged following this coarse filtration. Samples of pasture and distilled water (150 ml each) were measured and placed into 3.5 inch diameter pyrex jars. One hundred microliters of a 0.15 microgram per microliter acetone solution of a given insecticide were added to each jar with a calibrated micropipette; this gave an initial concentration of 0.1 ppm. The jars were then moved into the field and placed into the pasture water so that the background color was natural, the temperature was the same as for field water, and they were exposed to natural solar radiation. The duplicate samples of treated pasture and distilled water were extracted at the end of 0, 2, 4, and 8 hours of exposure. Pasture water, filtered as described above, was brought back into the laboratory and refrigerated for further tests (described below). Field water temperatures were measured periodically during the tests. The pH of the pasture waters used in the tests varied but all were between 7 and 9; the pH of the distilled water 6.5.

Laboratory tests - Tests on each collection of field water were conducted with the same insecticide as had been used in the respective field test. Laboratory tests were conducted in the same manner as was described for field tests, except that the jars were held in the dark, in constant-temperature

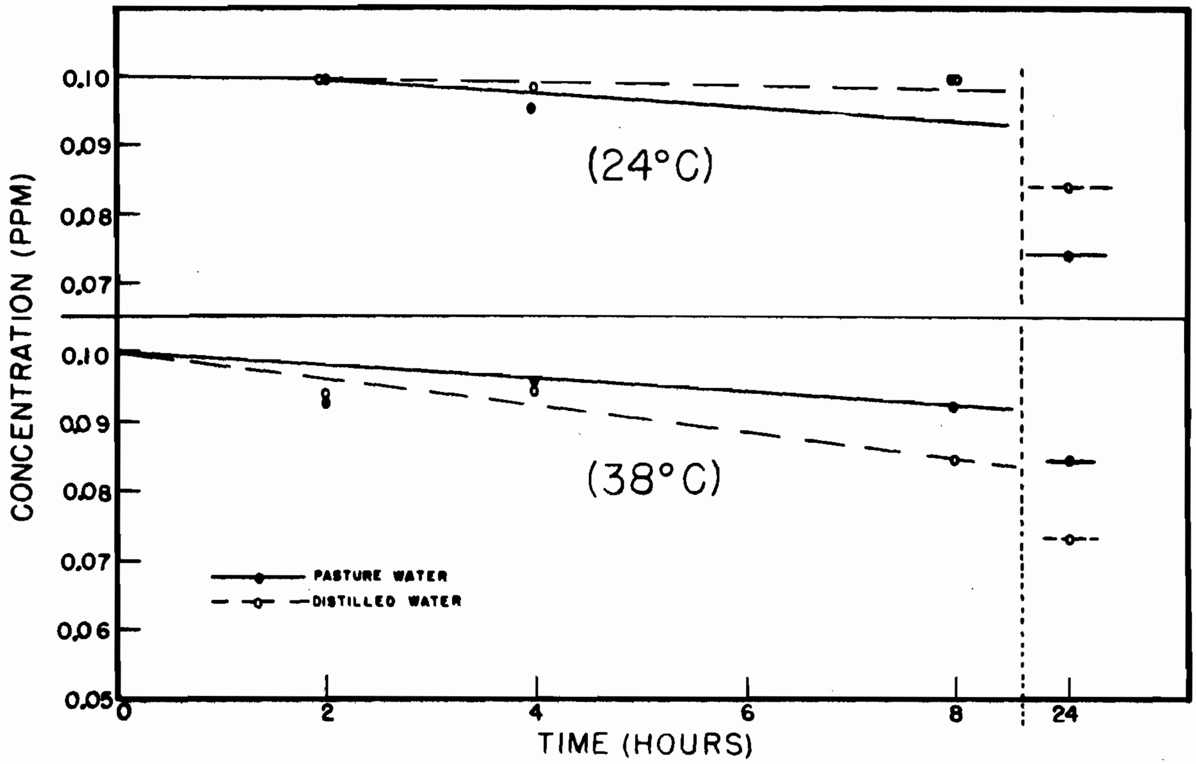


FIGURE 2 LABORATORY STABILITY OF FENTHION IN DISTILLED WATER AND JOAQUIN TOLEDO PASTURE WATER (COLLECTED 10-10-68) UNDER CONSTANT TEMPERATURE AND DARKNESS.

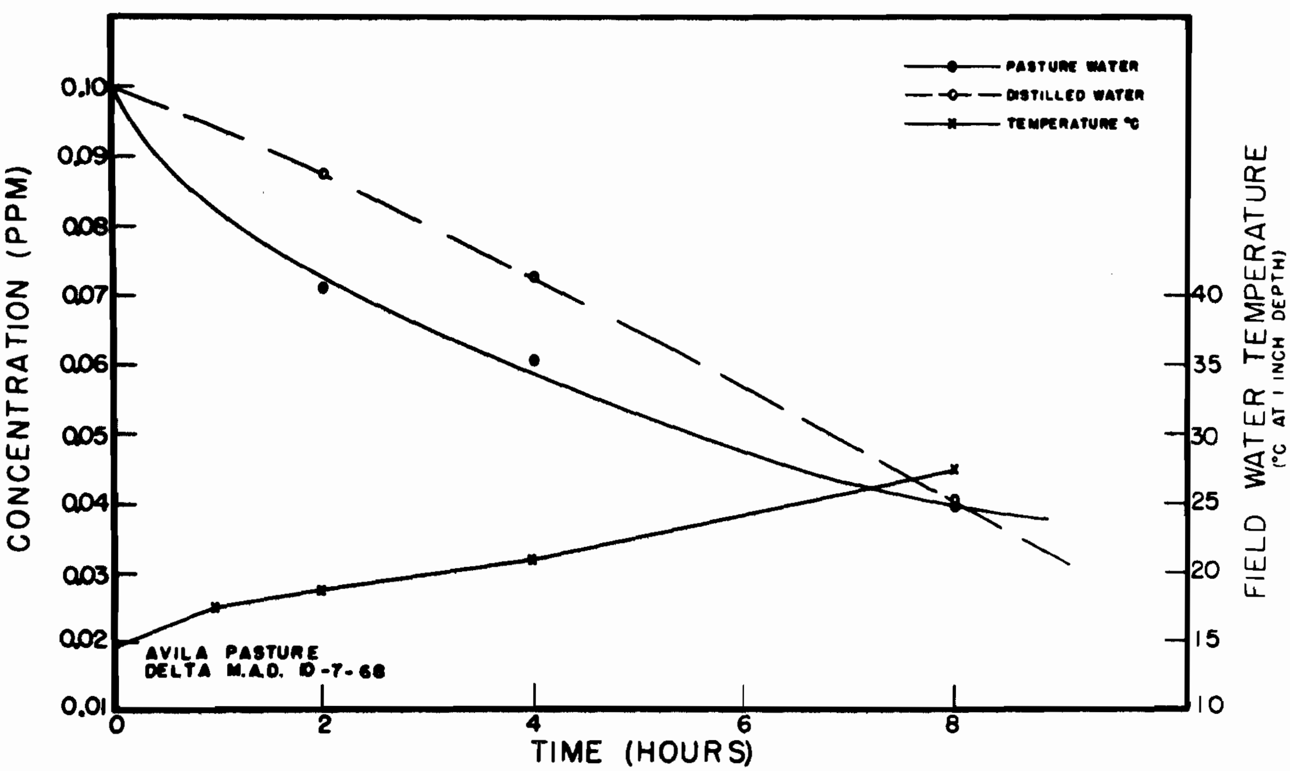


FIGURE 3 STABILITY OF FENTHION IN PASTURE AND DISTILLED WATER UNDER FIELD CONDITIONS.

cabinets and that, in some cases, treated jars were exposed to the experimental conditions for up to 24 hours before extraction. Each laboratory test was conducted at two different temperatures: 24° and 38° C; these temperatures were representative of the low and high water temperatures which were common under field conditions in mid-summer.

Glassware Treatment - In order to insure that the insecticide would not "plate out" on the sides and bottom of the glass jars during the field and laboratory tests, all jars were silanized as follows: the jars were thoroughly washed and dried, filled with a 5% solution of dichlorodimethylsilane in toluene, held for 10 minutes, emptied and then filled with anhydrous methanol. After the methanol was poured out and the jars dried, the effect of the silanization was apparent as the glass would not "wet". This treatment masks active groups, i.e., hydroxyl groups, and thereby eliminates sites where adsorption can occur.

Extraction Methods - At the end of the various post-treatment holding times, the water from a given jar was poured into a glass-stoppered bottle and 150 ml of an organic solvent were added. Chloroform was the extracting solvent for the parathion and Dursban samples, and methylene chloride was used for the fenthion samples. For water samples containing parathion or Dursban, hydrochloric acid was added to acidify the aqueous phase to pH 1, which is reported to improve the extraction and reduce the formation of emulsions (Warnick and Gaufin, 1965). This acidification could not be used with fenthion samples, as considerable loss of the compound resulted. The bottles were held overnight and then each was poured into a separatory funnel. After a one-hour partition, the organic phase was drawn off and the aqueous phase was re-extracted with a second aliquot of the organic solvent; after an additional one-hour partition, the second organic phase was drawn off and the combined organic phase was reduced to 1 ml in a rotating evaporator "in vacuo". Ten to 15 ml of methanol were then added and the volume was again reduced; n-hexane (distilled over sodium metal) was then added and the volume was reduced to about 0.5 ml. The latter was transferred with n-hexane into a graduated tube to a volume of 5.0 ml for gas-chromatographic analysis.

Gas chromatography - Parathion and Dursban: A Hewlett-Packard Model 5756 gas chromatograph equipped with an electron capture detector was used. The glass column was 6 feet by ¼ inch, packed with 1% (filter-coated) SE-30 on 100/200 mesh Gas-Chrom Q. The column temperature was 180°, the electron capture detector 340°C. (N_i^{63} source) and the injection port 200° C. The carrier gas was argon (95%) - methane (5%) and the flow rate was 60 ml per minute; another 60 ml per minute of the same gas mixture was used for purging the detector. Unknowns were quantitated by comparing peak heights to those of a standard curve. Fenthion: A Varian-Aerograph Model 615-D gas chromatograph equipped with a thermionic detector was used. The glass column was 5 feet by 1/8 inch and packed with 5% DC-200 (12,500 c.s.) on 60/80 mesh Gas-Chrom Q. The column and detector temperature was 180° C and the injection port 210° C. The helium carrier gas was held at 19 ml per minute; the detector gasses were hydrogen (20 ml/min) and air (175 ml/min).

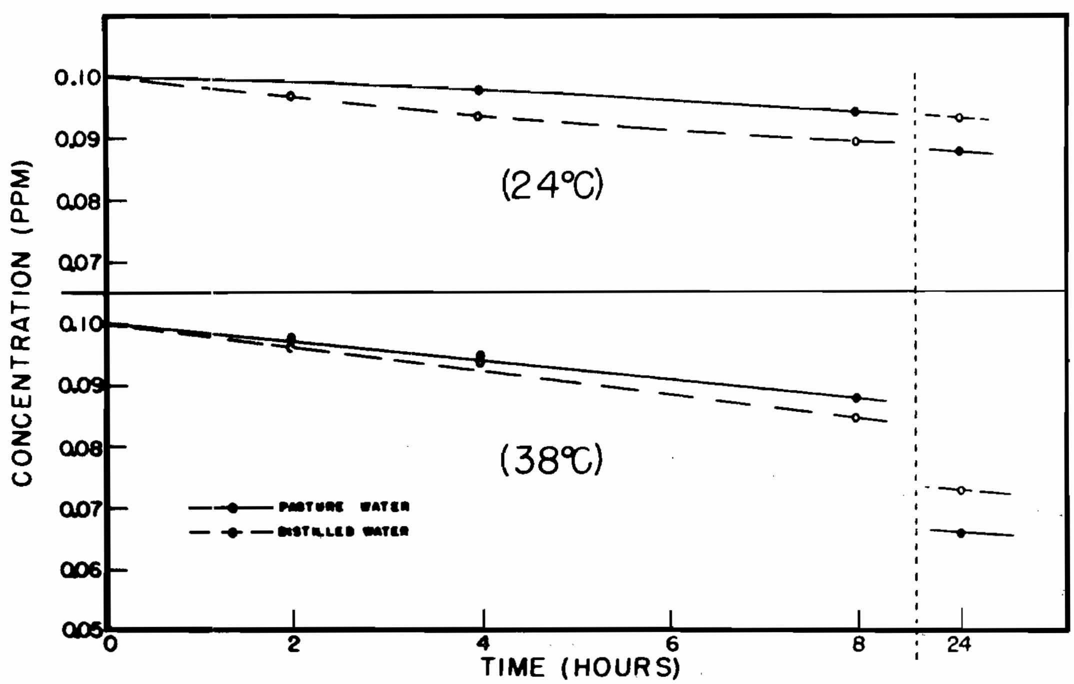


FIGURE 4 LABORATORY STABILITY OF FENTHION IN DISTILLED WATER AND AVILA PASTURE WATER (COLLECTED 10-7-68) UNDER CONSTANT TEMPERATURE AND DARKNESS.

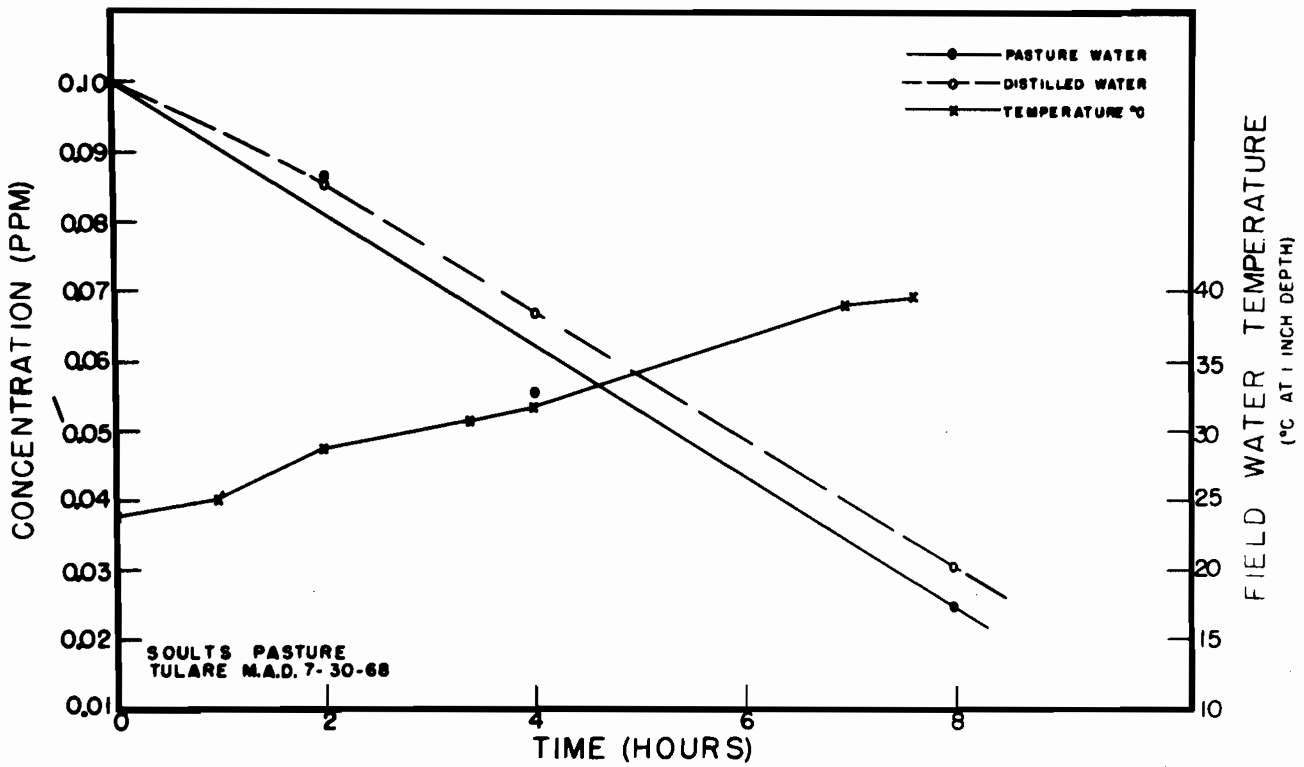


FIGURE 5 STABILITY OF DURSBAN IN PASTURE AND DISTILLED WATER UNDER FIELD CONDITIONS.

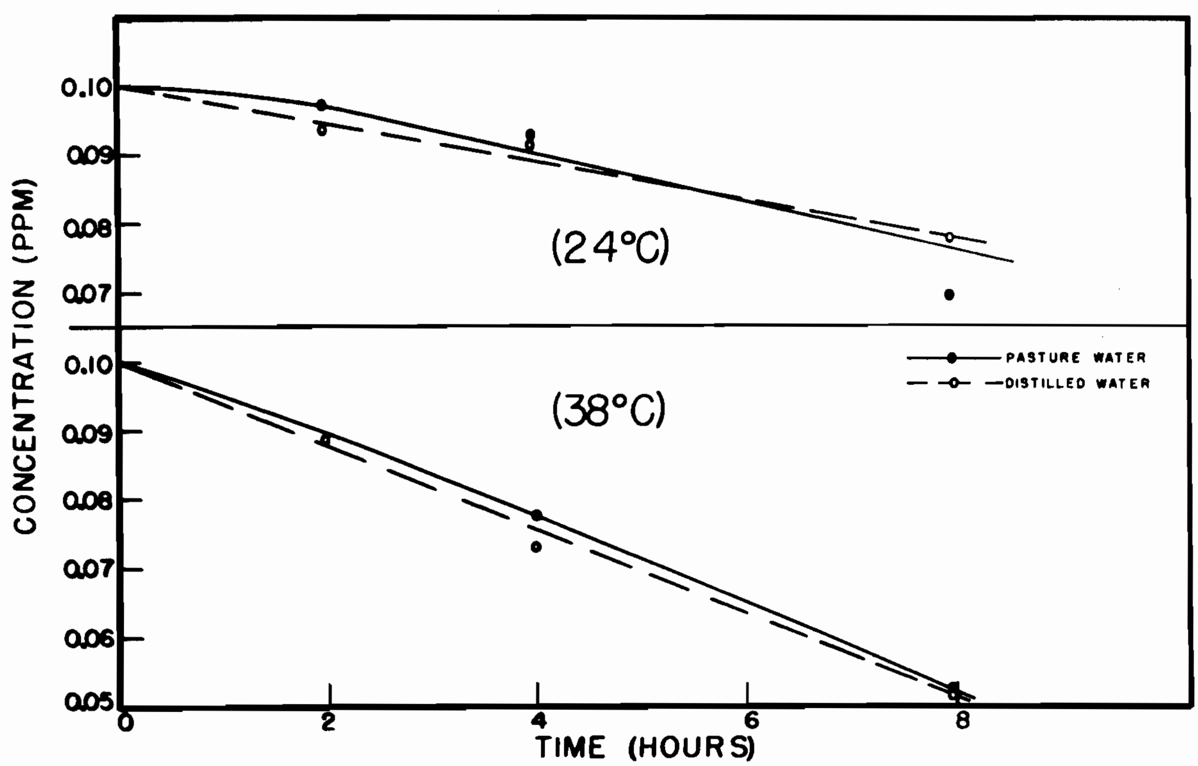


FIGURE 6 LABORATORY STABILITY OF DURSBAN IN DISTILLED WATER AND SOULTS PASTURE WATER (COLLECTED 7-30-68) UNDER CONSTANT TEMPERATURE AND DARKNESS.

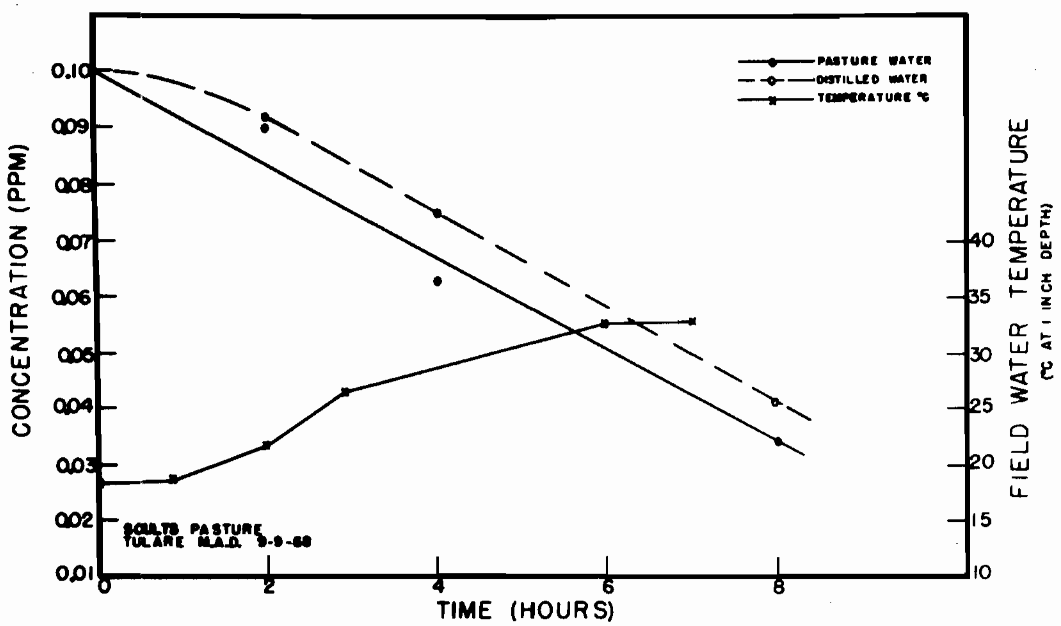


FIGURE 7 STABILITY OF DURSBAN IN PASTURE AND DISTILLED WATER UNDER FIELD CONDITIONS.

Results

Figures 1-4 show the stability of fenthion in two field tests and in two sets of laboratory tests. While the rate of loss of fenthion is less in distilled water in both field tests, the differences are small and indicate that water quality has little effect on stability. Differences in the stability of fenthion in the laboratory tests were less (Figures 2 and 4) than for field tests. Water temperature influences the stability of fenthion but only to a small degree. The great increase in fenthion stability in the laboratory, as compared to the field tests, appears to be due to the effect of light; this factor will be further studied and may have some practical value, e.g., evening rather than morning spraying may be more effective with fenthion.

Figures 5-8 show the stability curves for Dursban. As in the case of fenthion, Dursban was slightly more stable in distilled than in pasture water in the field tests, but the magnitude of the differences is quite small. Note that the two field tests with Dursban (Figures 5 and 7) were conducted in the same pasture in July and in September, and that there was no decrease in stability as the season progressed. It is apparent from the laboratory data that Dursban has much less hydrolytic stability than fenthion and that temperature has a much greater influence. The rates of decay of Dursban in the field tests were only slightly greater than those at 38° C in the laboratory. The relatively fast rate of loss curve for Dursban in water is inconsistent with the relatively long residual activities reported for this compound in impounded waters (Lembright, 1968; Sjogren and Mulla, 1968). Preliminary laboratory experiments have shown that Dursban adsorbs onto organic matter and is then protected from hydrolysis; this effect is presently under further investigation.

Figures 9-12 show the results for parathion; this compound has high hydrolytic stability under field and laboratory conditions. With parathion, as for fenthion and Dursban, the influence of water quality on stability is small and of no apparent practical significance. Temperature influences the rate of loss to a small extent, e.g., at 8 hours there is about 10% more loss at 38° than at 24° C, and light appears to have little, if any, effect.

Table 1 shows the half-lives for fenthion and Dursban under field conditions; the values for parathion are not given as the time interval was not long enough to allow a reasonable determination.

For many years the possible effects of alkaline pasture water on insecticide stability has been discussed. Gjullin and Peters (1952) studied the effect of alkaline pasture water on the insecticidal activity of toxaphene; no differences

Table 1. Half-lives (hours) for fenthion and Dursban® under field conditions (initial concentration 0.1 ppm).

Compound	Pasture Water	Distilled Water
Fenthion		
Test 1	5.6	6.8
Test 2	6.5	7.4
Dursban®		
Test 1	5.3	5.9
Test 2	6.1	7.0

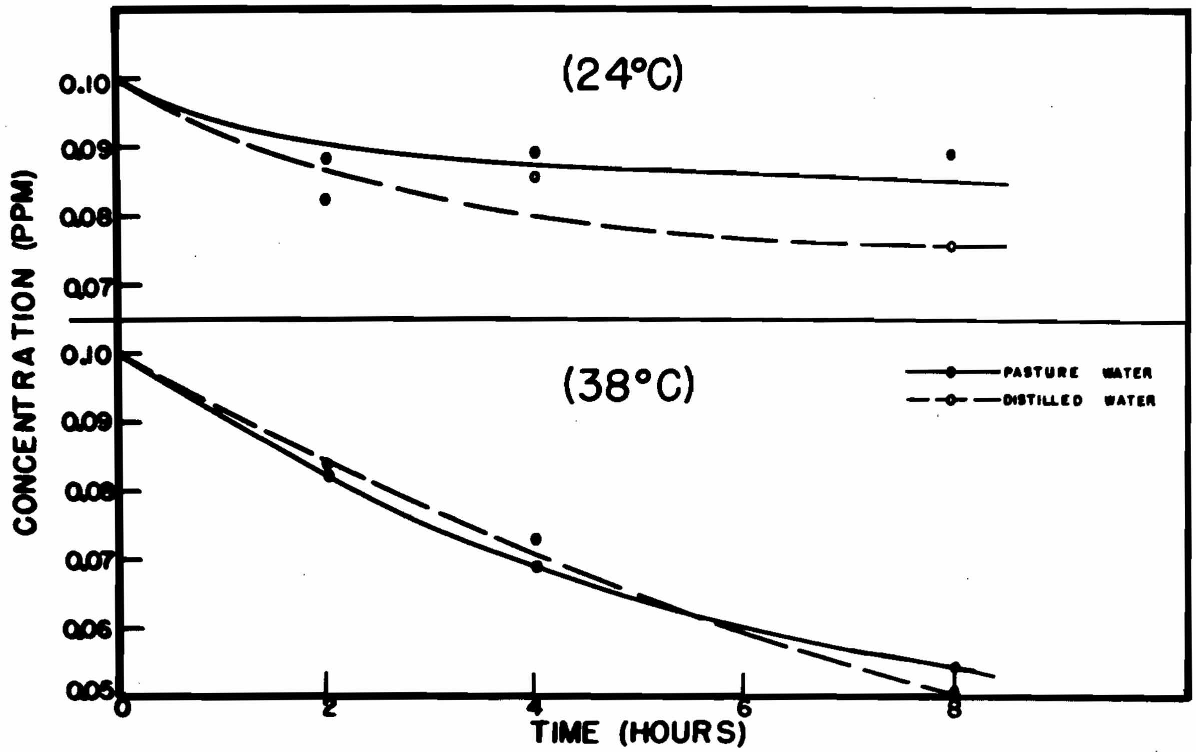


FIGURE 8 LABORATORY STABILITY OF DURSBAN IN DISTILLED WATER AND SOULTS PASTURE WATER (COLLECTED 9-9-68) UNDER CONSTANT TEMPERATURE AND DARKNESS.

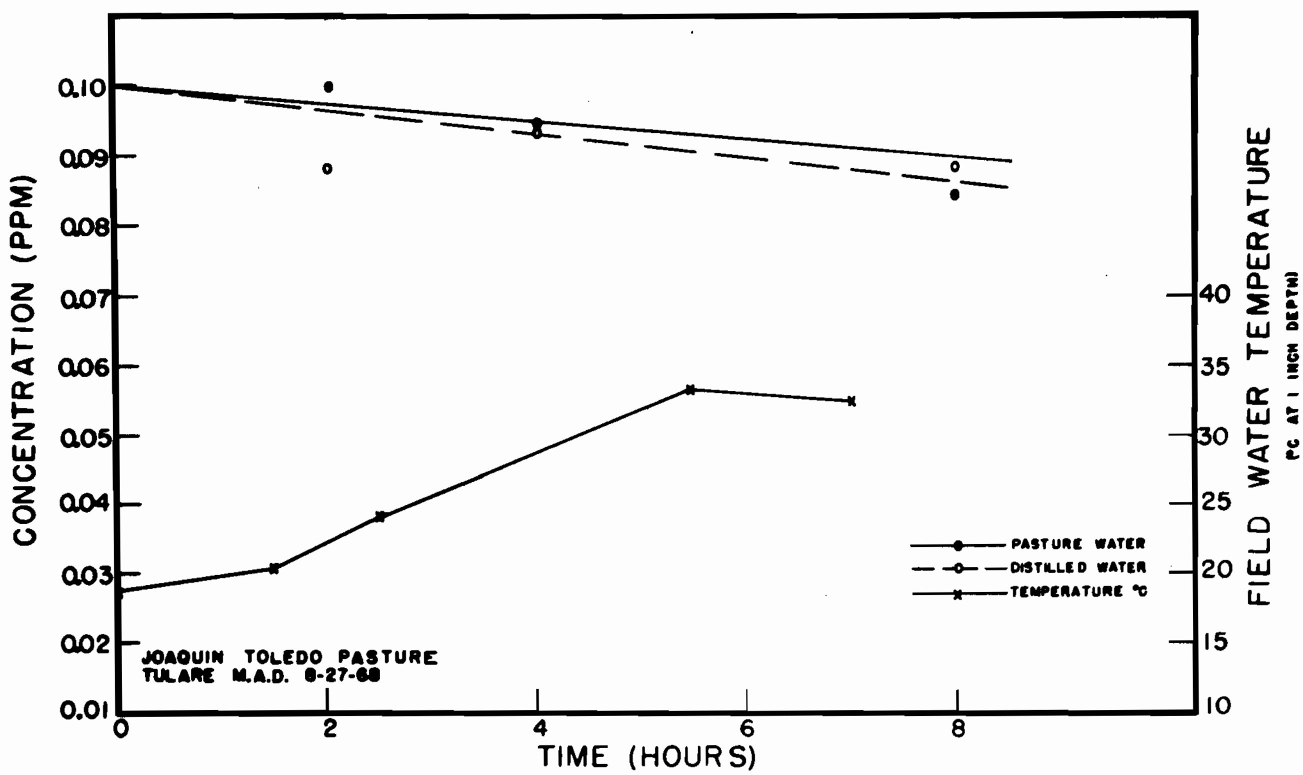


FIGURE 9 STABILITY OF PARATHION IN PASTURE AND DISTILLED WATER UNDER FIELD CONDITIONS.

were found when bioassays were conducted with water from alkaline and nonalkaline sources. These authors concluded, "It therefore appears that failure to toxaphene in this area is due to the resistance of the larvae and not to any effect of the alkaline water on the toxaphene emulsions." The present studies, which involved three organophosphorus compounds, were conducted at a meaningful concentration and involved nearly 400 quantitative analyses; no evidence was found that water quality exerts an important effect on insecticide stability. We conclude that water quality of San Joaquin Valley alkaline pastures does not have any practical effect on the performance of organophosphorus larvicides.

However, it is apparent that there is a significant relationship between alkaline pastures and control difficulties. The alkaline pastures in question are located on hard-pan soils which have poor drainage; these lands are difficult to farm and, therefore, are usually maintained as permanent pastures rather than being rotated to other higher return crops, as occurs in other areas. The continued presence of pastures results in a given area being treated very frequently, season after season, for the control of *A. nigromaculis*. We believe that this (selection pressure) explains why insecticide resistance first appears in these alkaline areas and that insecticide resistance is the significant cause of control difficulties.

There was no indication of any decrease in the stability of the compounds tested as the season progressed; thus, water quality does not appear to be related to this problem. Other factors that may account for these late season control difficulties will be studied during the coming season.

Acknowledgments

The authors gratefully acknowledge the assistance of the managers of the Tulare, Kings, and Delta Mosquito Abatement Districts for their help in selection of pastures and for assistance in conducting these tests. We are also very appreciative of the help of Mrs. P.A. Gillies of the California Department of Public Health who provided important background information on the study areas and made available bioassay data on treated pasture waters.

References Cited

Gjullin, C.M., and R.F. Peters. 1952. Recent studies of mosquito resistance to insecticides in California. Mosq. News 12:1-7.

Lembright, H.W. 1968. The use of Dursban® in the ultra low volume sprays in California mosquito control. Proc. Calif. Mosq. Control Assoc. 36:14 (Abstr.).

Schaefer, C.H. 1968. The University of California mosquito research program at Fresno. Proc. Calif. Mosq. Control Assoc. 36:63-65.

Sjogren, R.D., and M.S. Mulla. 1968. Drip application of three organophosphorus insecticides for mosquito control. Proc. Calif. Mosq. Control Assoc. 36:40 (Abstr.).

Warnick, S.L., and A.R. Gaufin. 1965. Determination of pesticides by electron capture gas chromatography. J. Amer. Water Works Assoc. 57:1023-1027.

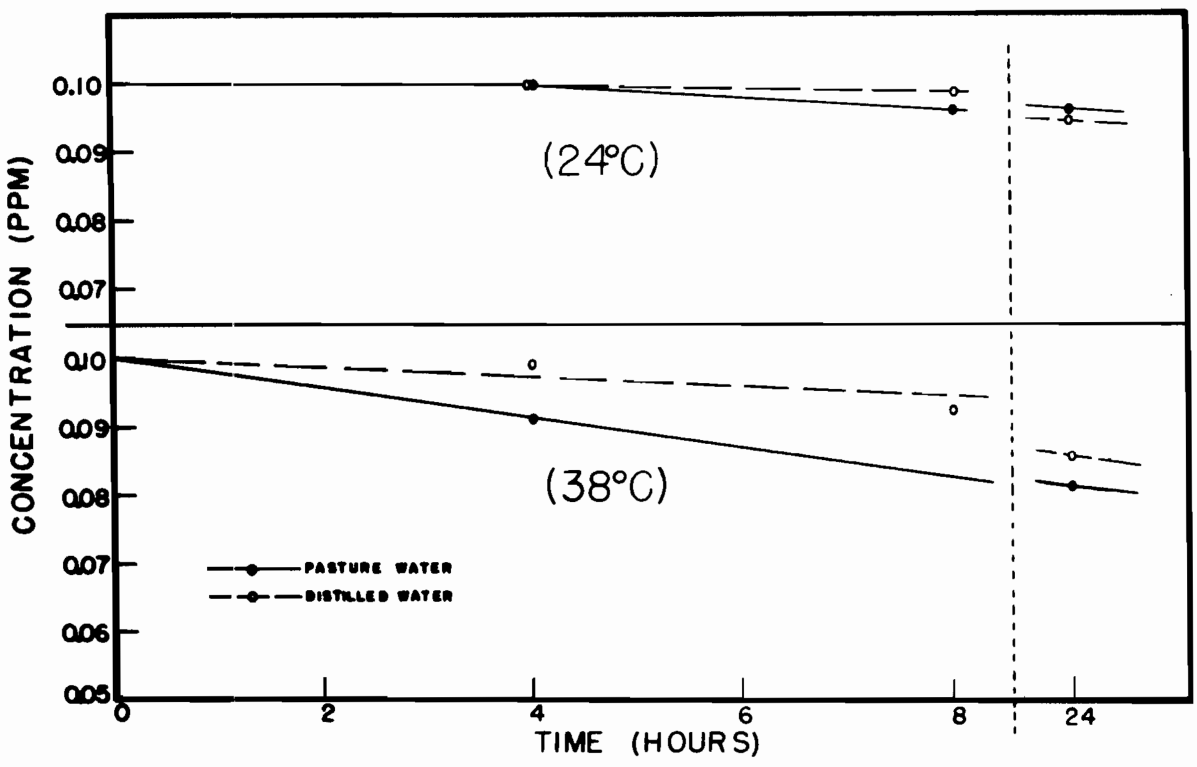


FIGURE 10 LABORATORY STABILITY, PARATHION IN DISTILLED WATER AND JOAQUIN TOLEDO PASTURE WATER (COLLECTED 8-27-68) UNDER CONSTANT TEMPERATURE AND DARKNESS.

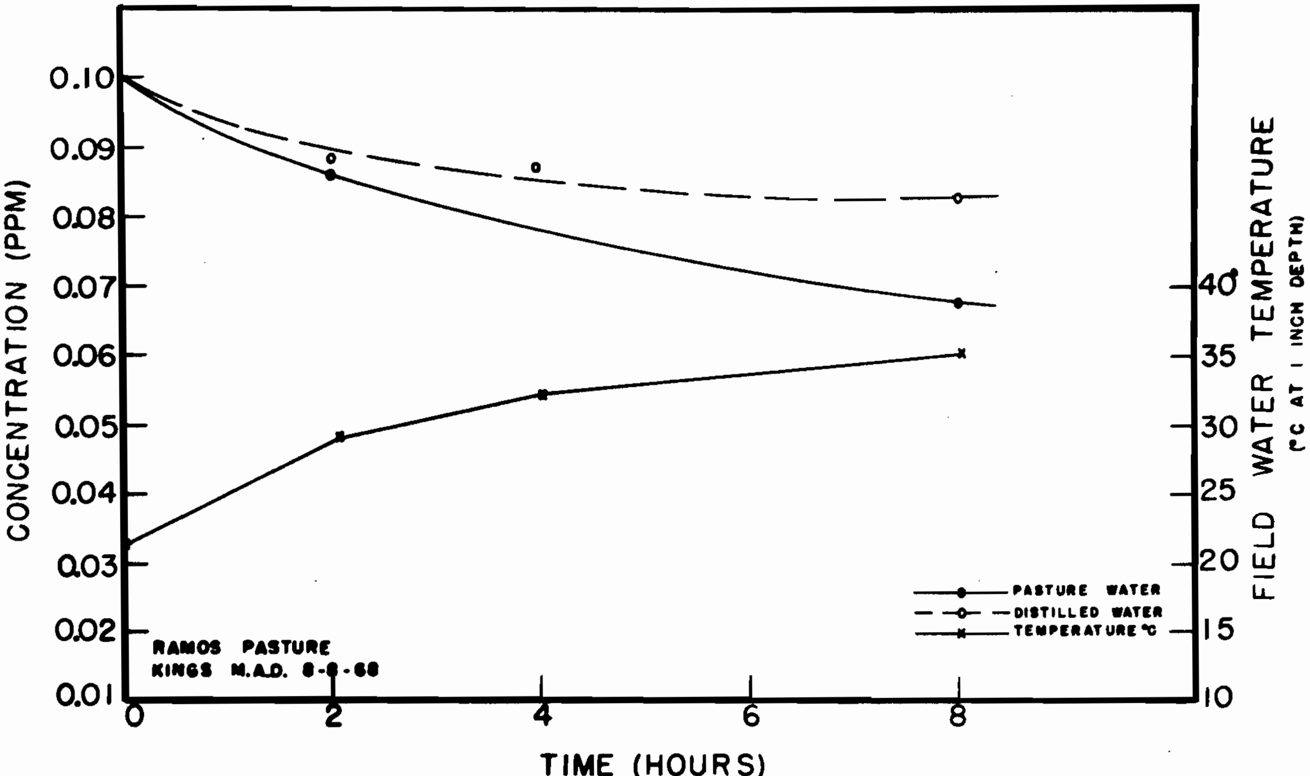


FIGURE 11 STABILITY OF PARATHION IN PASTURE AND DISTILLED WATER UNDER FIELD CONDITIONS.

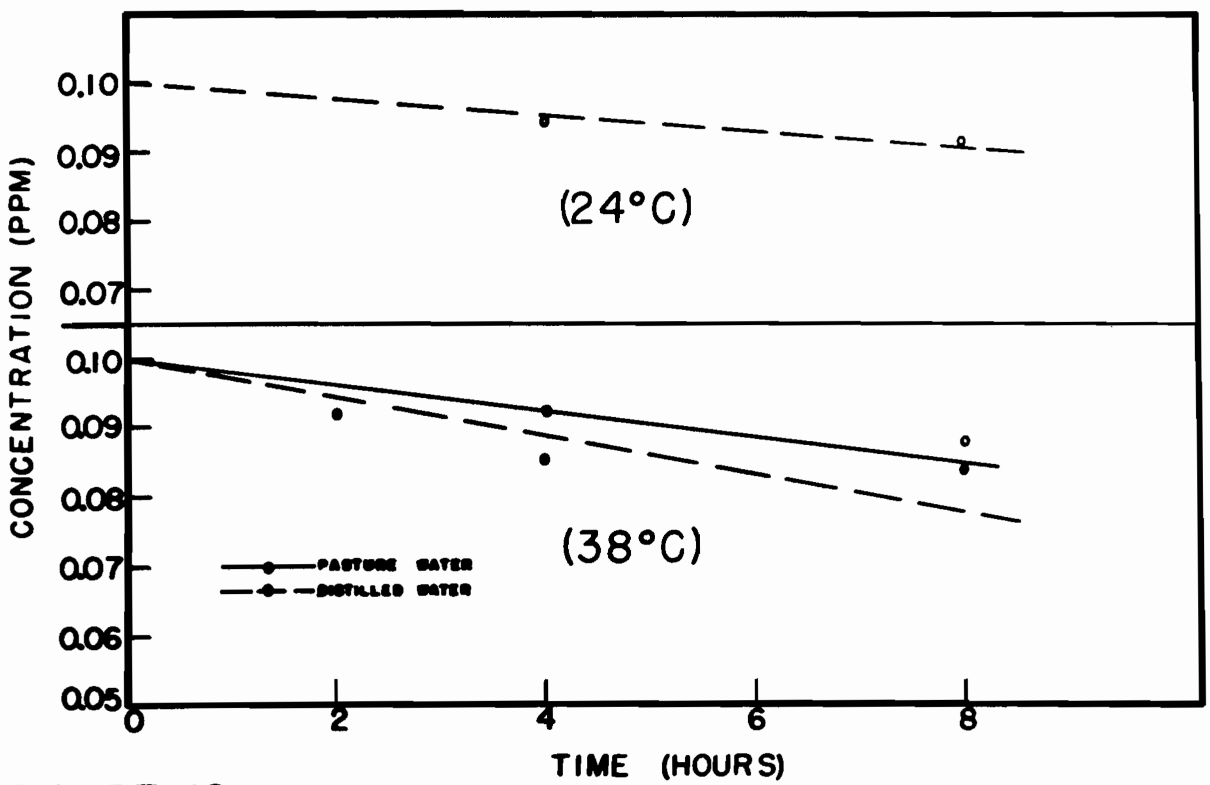


FIGURE 12 LABORATORY STABILITY OF PARATHION IN DISTILLED WATER AND RAMOS PASTURE WATER (COLLECTED 8-8-68) UNDER CONSTANT TEMPERATURE AND DARKNESS.

FIELD AND LABORATORY INVESTIGATIONS ON THE CONTROL OF SUSCEPTIBLE AND RESISTANT PASTURE MOSQUITOES

M.S. Mulla and H.A. Darwazeh

Department of Entomology
University of California, Riverside

Irrigated pasture mosquitoes such as *Aedes nigromaculis* (Ludlow) and *A. melanimon* Dyar pose a serious pest problem in the San Joaquin and Sacramento valleys of California. Due to the large expanse of breeding sources the problem is acute, especially in Fresno, Kern, Kings and Tulare counties. The pasture mosquitoes are very annoying to farm workers, neighboring communities and livestock, and they are extremely difficult to control. Lack of adequate control is attributed to several factors such as drift of control agents, lack of penetration of control agents through the plant canopy and the rapid development of resistance to chlorinated hydrocarbons and organophosphorus larvicides. Emulsifiable concentrates failed to achieve sufficient control when applied by air due to dense vegetative growth which prevented the spray particles from penetrating into the breeding niches (Fowler et al., 1963). In Kings and Tulare counties, the problem is far more critical due to the presence of multiresistant strains of pasture mosquitoes to organophosphate insecticides such as ethyl parathion, methyl parathion, and fenthion (Baytex®) (Lewallen and Peters, 1966). The newly developed larvicides including ABATE® and Dursban®, at times, failed to achieve adequate control during the 1968 season in Tulare County. Further studies on resistance are necessary to determine the extent of resistance development to ABATE and Dursban in pasture mosquitoes in that area.

New control techniques as well as new effective mosquito larvicides are needed to control the pasture mosquitoes most efficiently and economically. Mulla et al. (1969a) evaluated 55 new compounds in the laboratory against 4th instar larvae of *Culex pipiens quinquefasciatus* (Say); those chemicals which showed high biological activity against the *Culex* species in the laboratory were further evaluated against *Aedes aegypti* (L.) in the laboratory and *Culex tarsalis* Coquillet, *C. peus* Speiser and *Anopheles pseudopunctipennis franciscanus* McCracken in experimental ponds.

Mulla et al. (1969b) achieved excellent control of mosquito larvae in pastures by dripping emulsifiable concentrates containing 2-4 lbs per gallon of actual material into the irrigation water. Laboratory analysis of mud samples obtained from treated area with the drip method indicated the persistence of Dursban in the field for 21 days. The following studies were initiated to determine whether one insecticide drip application will yield sufficient control for more than one irrigation, and to evaluate the efficacy of new promising mosquito larvicides against susceptible and resistant strains of *Aedes nigromaculis* and *Aedes melanimon*.

Methods and Materials

Methods for insecticidal evaluation in the laboratory were described in previous studies by Mulla et al., (1966). One percent stock solution (w/v) of the technical grade of each compound was prepared in acetone, and serial dilutions were made as needed. Twenty 3rd and 4th instar larvae were place in 100 ml of tap water per 4-oz dixie cup. The proper strength solution then was added to yield the required dosage in ppm (1 ml or less). Each concentration was replicated twice and tested two or three times. Mortality count was obtained 24 hours after treatment, and the average percent mortality was plotted against log concentration in ppm on a log probit paper. The LC_{50} and LC_{90} values were determined by inspection. All solutions were kept under refrigeration when not in use.

Mosquito larvae evaluated in the laboratory were collected from irrigated pastures at different times and tested within 30-60 minutes after collection. Costa pasture larvae (Kings County), were 98 percent *A. nigromaculis*, while Smith pasture mosquitoes (Kern County) included both *A. nigromaculis* and *A. melanimon.* Smith pasture *Aedes* are known to be resistant to chlorinated hydrocarbons and moderately resistant to organophosphate larvicides. Costa pasture mosquitoes are highly resistant to chlorinated hydrocarbons and several organophosphorus insecticides.

The new mosquito larvicides were evaluated against pasture mosquitoes in the field in 1/32 acre size plots. Two or three chemicals were evaluated at a time at 2-3 different dosages. Each dosage was replicated twice, and two plots per test were left untreated for checks. Pre-treatment and 24-hour post-treatment larval counts were taken by dipping 15 dips per plot. Insecticidal formulations used in the tests were either emulsifiable concentrates, wettable powders or granules. The emulsifiable concentrates and wettable powders were diluted or suspended in 1000 ml of water and applied with a one-gallon hand sprayer.

Methods used for injecting the mosquito larvicides into the irrigation water for the control of pasture mosquitoes were described in previous studies by Mulla et al. (1969b). Emulsifiable concentrates containing 2-7 pounds per gallon of actual material of ABATE, Dursban and fenthion were dripped into the irrigation water by using either the constant head metering assembly or the adjustable electrical pump as described elsewhere (Mulla et al. 1969b).

Experiment I. - The electrical pump was set at 40 percent stroke length, and attached to a well with 2000 gpm capacity. A total volume of 2835 ml of Dursban (EC 4) was applied in 24 hours treating 12 checks (50 ft x ¼ mile) amounting to 18 acres, yielding an average dosage of 0.12 ppm. After the Dursban application, the pump stroke length was increased to 70 percent, and 4880 ml of fenthion (EC 4) were applied in 24 hours treating 12 checks (same size) at the rate of 0.21 ppm. Following the fenthion treatment, 14 more checks (21 acres) were treated with 4380 ml of ABATE

(EC 4) in 24 hours, at the rate of 0.20 ppm in the flowing water.

Experiment II. - The constant head metering assembly was utilized to drip one gallon of Dursban (EC 2) in 24 hours, treating 7 checks (32 ft x ½ mile), an area of 13.6 acres, at a dosage rate of 0.11 ppm (0.15 lb/acre). The chemical was dripped directly into a well stand. The pump capacity was 1432 gpm.

Experiment III. - A volume of 6500 ml of ABATE (EC 2) was dripped into water from a well pumping 1432 gpm. The chemical was applied through the constant head metering assembly, treating 7 checks (36 ft x ½ mile) amounting to 14 acres in 24 hours, at a dosage rate of 0.20 ppm (0.24 lb/acre).

Experiment IV. - An electrical pump was installed at a well pumping 2000 gpm, and was set at 65 percent stroke length to deliver 200 ml per hour. After treating 14 checks (50 ft x ¼ mile) with ABATE (EC 4) at the rate of 0.20 ppm in 24 hours, the pump stroke length was reduced to deliver 100 ml per hour to apply fenthion (EC 7) at the rate of 0.20 ppm. Eleven checks were treated with this rate of fenthion, followed with 30 checks to be treated with Dursban (EC 4) at dosage rate of 0.10 ppm.

Experiment V. - A volume of 5670 ml of fenthion (EC 2) was applied in 20 hours treating 10 checks (32 ft x ½ mile) amounting to 20 acres. The chemical was dripped through the constant head metering assembly directly into the water being pumped at 1500 gpm, at a dosage rate of 0.20 ppm (0.15 lb/acre).

In order to study the persistence of materials applied by the drip method during the subsequent two irrigations an area was located in Smith Pastures (northwest corner of Kern County) producing heavy populations during the 1967 season. Prior to the introduction of the chemical into the irrigation water, 7-14 checks were irrigated without treatment, followed with the treated checks. Forty-eight hours after flooding, larval count was taken by dipping in the middle four checks of each treatment and the untreated checks. Ten dips per location were taken at 500 and 1000 ft from water valve in ¼ mile checks, and 500, 1000, 1500 and 2000 ft in ½ mile checks. The larvicides were applied during the first irrigation, and the treated and untreated areas were inspected 48 hours after flooding. This procedure was followed after the first (when larvicides were dripped), second and third irrigations. No larvicide was introduced during the second or third irrigations. Suppression of larval populations during the second and third irrigations was an indication of the extent of larvicidal residues during the two irrigations.

Fenthion and Carbofuran® granules containing 2 percent of active ingredients were evaluated in irrigated pastures as pre- and post-hatch treatments. In the post hatch treatment, the granules were broadcasted by hand, and methods of evaluation used were described previously for the evaluation of emulsifiable concentrate insecticides. However, Carbofuran granules also were applied by air in Smith pasture at the rate of 5 lbs of 2 percent material per acre (0.1 lb/acre actual). Granules were applied from 30 ft. elevation, covering 63 ft in width per swath. Slight north wind (2-3 mph) prevailed during application, and flight pattern was from east to west. Larval count was taken prior and 24 hours after application, and field population consisted of 2nd to 4th instar larvae.

Granules for the pre-hatch treatment were applied with a corn seeder 48 hours before flooding. Six ¼ mile-long checks were treated, one check per concentration, and each concentration was replicated twice. Between treated checks one check was left untreated to prevent the highly concentrated water from mixing with the water in the control check, and water in check treated with the lower concentration. Forty-eight hours after flooding, the treated checks and the controls were inspected for larval breeding by dipping 50-100 dips per check.

Results and Discussion

Species Composition in Irrigated Pastures - Samples of larvae of *Aedes* species were taken from Smith pasture located in the northwest corner of Kern County adjacent to Kings County. The larvae were determined to species and their percentages calculated. The earliest collection taken on April 25, 1968, showed *A. melanimon* to be predominent, constituting 75% of the population, while *A. nigromaculis* comprised 25% of the population (Table 1). On May 13,

Table 1. Species composition of irrigated pasture mosquitoes collected in Smith pasture, Kern County, California (1968).

	No. of larvae/sample				
		A. melanimon		*A. nigromaculis*	
Date	Total no.	No./sample	(%)/sample	No./sample	(%)/sample
April 25	128	96	75	32	25
May 13	215	85	40	130	60
June 18	303	101	33	202	66
June 26	295	74	25	221	75
July 12	408	167	40	241	60
July 24	473	139	30	334	70
August 1	494	105	21	389	79

Table 2. Activity of new insecticides against 3rd and 4th instar larvae of pasture *Aedes* mosquitoes. (June–August 1968)

Insecticide	Chemical Description
Dursban®	*0, 0*–diethyl *0*–3, 5, 6–trichloro–2–pyridyl phosphorothioate
Bay 78182	(0–chlorophenyl) glyoxylonitrile oxime 0, 0–diethyl phosphorothioate
Fenthion	*0, 0*–dimethyl *0*–[4–(methylthio)–m–tolyl] phosphorothioate
ABATE®	*0, 0, 0', 0'*– tetramethyl *0, 0'*–thiodi–p–phenylene phosphorothioate
EPN	Ethyl–p–nitrophenyl thionobenzenephosphonate
Bay 79330	(Diethoxythiophosphoryloximino)–2, 6-dichlorophenyl acetonitrile (α–isomer)
Methyl parathion	*0, 0*–dimethyl *0*–p–nitrophenyl thiophosphate
Bay 77488	*0, 0*–diethyl thiophosphoryl *0*–a–cyanobenzaldoxime
Bay 78755	(Diethoxythiophosphoryloximino)–2, 6–dichlorophenyl acetonitrile (β isomer)
Carbofuran	2, 3–dihydro–2, 2–dimethyl–7–benzofuranyl methylcarbamate
Ethyl parathion	*0, 0*, diethyl–0–p–nitrophenylphosphorothioate
C–9491	*0, 0*–dimethyl–0–2, 5–dichloro–4–iodophenyl thiophosphate
AKTON®	*0*–(2–chloro–1–(2, 5–dichlorophenyl) vinyl) *0, 0*–diethyl phosphorothioate
Neo pynamin®	3, 4, 5, 6–tetrahydrophthalimi=dimethyl–2, 2–dimethyl–3–(2–methyl popenyl) cyclopro=panecarboxylate
Bay 69047	*0, 0*–dimethyl–*0*–(4–nitro–3–isopropyl–mercaptophenyl)–thionophosphate
NIA–17370	(5–Benzyl–3–furyl) methyl (±) cis–trans–2–2–dimethyl–3–(2–methyl–1–propenyl)= cyclopropane–1–Carboxylete

1968, the former species was only 40% and this percentage either remained the same or declined further with the progress of the season. The last collection taken on August 1, 1968, showed only 21% of the larvae to belong to *A. melanimon* and the remaining 79% to *A. nigromaculis*. It is possible that the ratio of the two species further increased in favor of *A. nigromaculis* toward the end of the season. This aspect will be further studied.

Insecticidal Evaluations - Chemical descriptions of the materials evaluated against pasture mosquitoes are included in Table 2. Most of the materials evaluated belong to the general group of organophosphorus insecticides.

Most of the materials were evaluated against a moderately susceptible and a highly resistant strain of pasture mosquitoes (Table 3). Dursban, Bay 78182, ABATE, fenthion, EPN and Bay 79330 were highly effective against both resistant and susceptible strains of pasture mosquitoes. Based on the LC_{90} (ppm) levels of all the chemicals evaluated, Costa pasture (Kings County) larvae were 2-32 times more tolerant to these chemicals than were Smith pasture larvae (Kern County). Costa pasture larvae were 2 times more resistant to EPN, Bay 77488, C-9491 and Neo pynamin, 3

Table 3. Laboratory evaluation of various insecticides against susceptible and resistant strains of pasture *Aedes* mosquitoes. (June–September 1968)

	LC_{50} (ppm)		(x)	LC_{90} (ppm)		(x)
Chemical	Smith	Costa	Resistance	Smith	Costa	Resistance
Dursban®	0.0004	0.0017	4	0.0007	0.0029	4
Bay 78182	0.0005	0.0023	4	0.0008	0.0050	6
Fenthion	0.0005	⟨0.0040	–	0.0012	⟨0.0040	–
ABATE®	0.0008	0.0050	6	0.0018	0.0100	6
EPN	0.0009	0.0021	3	0.0025	0.0042	2
Bay 79330	0.0010	–	–	0.0030	–	–
Methyl parathion	0.0012	0.0320	25	0.0024	0.0780	32
Bay 77488	0.0012	0.0021	2	0.0024	0.0042	2
Bay 78755	0.0015	–	–	0.0030	–	–
Furadan® (carbofuran)	0.0027	0.0230	10	0.0060	0.0450	7
Ethyl parathion	0.0030	0.0450	16	0.0060	0.1200	20
C–9491	0.0030	0.0086	3	0.0065	0.0155	2
AKTON®	0.0030	–	–	0.0065	–	–
Neo pynamin®	0.0070	0.0070	2	0.0070	0.0140	2
Bay 69047	0.0070	0.0100	2	0.0100	0.0320	3
NIA–17370	0.002	⟩0.0400	20	0.0400	⟨0.0600	–

Table 4. Field evaluation of new larvicides against pasture *Aedes* mosquitoes.

Chemical and formulation	Dosage lb/acre	Average number of larvae/dip Pre-treat	Post-treat	(%) mortality
C–9491 EC 3	0.01	43	2	95
C–9491 EC 3	0.05	38	0	100
C–9491 EC 3	0.10	51	0	100
AKTON® EC 2	0.01	21	2	90
AKTON® EC 2	0.05	41	1	98
AKTON® EC 2	0.10	84	0	100
–	Check	24	28	0
Bay 79330 EC 4	0.05	12	2	84
Bay 79330 EC 4	0.10	18	1	94
Bay 77488 EC 4	0.05	36	3	92
Bay 77488 EC 4	0.10	65	3	95
Bay 77488 EC 4	0.20	45	2	96
Bay 78755 EC 4	0.05	50	3	94
Bay 78755 EC 4	0.10	37	2	95
Bay 78755 EC 4	0.20	72	3	97
–	Check	42	45	0
Bay 79845 (75%) WP	0.01	116	51	53
Bay 79845 (75%) WP	0.05	175	2	99
Bay 79845 (75%) WP	0.10	248	3	99
Bay 75546 (50%) WP	0.01	130	43	67
Bay 75546 (50%) WP	0.05	161	2	99
Bay 75546 (50%) WP	0.10	233	4	99
–	Check	114	129	0

times to Bay 69047, 4 times to Dursban, 6 times to Bay 78812 and ABATE, 7 times to carbofuran, 20 times to ethyl parathion and 32 times to methyl parathion, as compared to Smith pasture larvae.

Table 4 shows several chemicals which were highly effective for the control of pasture mosquitoes when applied as an aqueous spray. Complete control was obtained with C-9491 at 0.05 lbs per acre, and AKTON®, Bay 78182, Bay 75546 and Bay 79845 at a rate of 0.1 lbs per acre yielded 100% control of the larvae. Bay 77488, Bay 79330, Bay 69047, EPN and NIA-17370 yielded 96, 94, 86, 76 and 57 percent mortality, respectively, at 0.1 lbs per acre.

Table 5. Evaluation of granular insecticides against larvae of *Aedes* in irrigated pastures.

Chemical and formulation (%)	Source	Carrier and Size	Dosage lb /acre	Average no. of larvae/dip Pre-treat	Post-treat	(%) Mortality
			Post-Hatch			
Fenthion 2[1]	Occ. Chem	Fertilizer (10/20)	0.10	155	0	100
Fenthion 2[1]	Occ. Chem	Fertilizer (10/20)	0.20	170	0	100
Check	–	–	–	165	180	0
Carbofuran 2[1]	Niagra	Sand Core (15/30)	0.05	12	3	83
Carbofuran 2[1]	Niagra	Sand Core (15/30)	0.10	11	1	85
Carbofuran 2[1]	Niagra	Sand Core (15/30)	0.25	9	0	100
Check	–	–	–	9	13	0
Carbofuran 2[2]	Niagra	Sand Core (15/30)	0.10	11	0.15	99
Carbofuran 2[2]	Niagra	Sand Core (15/30)	0.20	19	0.15	99
Check	–	–	–	13	26	0
			Pre-Hatch			
Carbofuran 2[1]	Niagra	Sand Core (15/30)	0.05	–	3	66
Carbofuran 2[1]	Niagra	Sand Core (15/30)	0.10	–	4	59
Carbofuran 2[1]	Niagra	Sand Core (15/30)	0.25	–	0	100
Check	–	–	–	–	9	0

[1]Smith Pastures, Kern County. [2]Costa Pastures, Kings County.

Table 6. Mosquito larvicides persistence in irrigated pastures when dripped into irrigation water.

Chemical and formulation	Dosage		Average no. of larvae/dip at indicated distance from water valve (ft.)											
			500			1000			1500			2000		
	PPM	lb/acre	A	B	C	A	B	C	A	B	C	A	B	C
Dursban® EC 4	0.10	–	0	3	14	9	22	25						
Check	–	–	107	64	55	134	54	80						
Dursban® EC 2	0.11	0.15	0	0	0	0	0	0	0	0	1	0	81	168
Check	–	–	dry	dry	dry	28	49	29	81	120	70	140	175	169
Dursban® EC 4	0.12	–	0	0	17	0	0	27						
Check	–	–	18	79	83	140	103	83						
ABATE® EC 4	0.20	–	0	1	11	0	23	19						
Check	–	–	108	64	55	134	54	80						
ABATE® EC 4	0.20	00.22	0	0	0	0	1	57						
Check	–	–	18	79	83	140	103	83						
ABATE® EC 2	0.20	0.24	0	0	0	0	0	41	4	8	41	158	132	123
Check	–	–	dry	dry	dry	107	82	122	129	104	128	171	134	140
Fenthion EC 2	0.20	0.15	0	0	–	0	2	–	0	14	–	0	30	–
Check	–	–	dry	dry	–	0	4	–	2	18	–	25	27	–
Fenthion EC 7	0.20	–	0	5	20	0	31	68						
Check	–	–	108	64	55	134	54	80						
Fenthion EC 4	0.20	–	0	30	dry	0	51	68						
Check	–	–	18	79	83	140	103	83						

A. First irrigation with treatment.
B. Second irrigation without treatment.
C. Third irrigation without treatment.

Results of fenthion and carbofuran granules in Table 5 indicate both chemicals were effective against both strains of larvae when applied at 0.1 lbs per acre. However, complete mortality was achieved with fenthion and carbofuran in the post-hatch treatments at 0.1 lbs per acre. Carbofuran aerial application also achieved complete control at the same rate. Only 0.25 lbs per acre of carbofuran rendered complete control in the pre-hatch treatment. This could be due to possible lack of penetration of pasture grass when the materials were applied. Aerial application of granules would yield better penetration and therefore would be more effective.

Drip application - From preliminary information, Mulla et al. (1969a), one insecticidal application with the drip method could control mosquito larval breeding in irrigated pastures for several subsequent floodings. In order to determine the effectiveness of one application during subsequent flooding, irrigated pastures were treated at the rate of 0.10 ppm of Dursban and 0.20 ppm of ABATE and fenthion. Results are presented in Table 6 which show that fenthion at 0.20 ppm gave complete control in both ¼-and ½-mile long checks for one irrigation only. At the rate of 0.11 ppm Dursban yielded complete control during the first flooding in ½-mile checks and up to 2000 ft from the water valve during the second and third irrigation. Also complete control was obtained with Dursban in ¼-mile checks for two consecutive irrigations at 0.12 ppm. Dursban at 0.1 ppm in another test failed to control mosquito breeding in ¼-mile checks, possibly due to the backing up of tail water at the lower end of the field, leading to incomplete control at the lower end of the field. ABATE also prevented larval breeding in ¼-mile checks at 0.20 ppm for two consecutive irrigations, except where tail water was present in the lower end of the field. In this treatment larvae were recovered by dipping after the second flooding, 1000 ft from water valve. In ½-mile long checks, the same rate of ABATE prevented larval breeding up to 1500 ft and reduced breeding considerably up to 2000 ft during the two subsequent irrigations. No control was obtained beyond 2000 ft from water valve, due to the presence of cattle tracks across the lower end of the field, which permitted untreated water to mix with the treated water. Also tail water from the adjacent untreated checks might have backed up into the treated area.

Assessment of larval breeding in small plots where tail water came from untreated checks and mixed with water from the treated checks poses some problems. In the final analysis such assessment should be carried out in large plots, using one half or more of a given field for treatment and the other half or less as untreated plot. It is desirable to use the first half of the field (irrigated first) for treatment and the remaining portion for untreated checks. This scheme will likely result in proper evaluation of the long-term efficacy of drip application of mosquito larvicides.

Strip Pre-Hatch Treatment of Irrigated Pastures - One experiment was conducted in which 2% granular formulations of carbofuran were applied at the rate of 0.2 lb/acre actual. One-half mile long pasture checks were divided into 4 quarters, the upper, the second, the third, and the fourth quarter from the valve. Each quarter was about 600 feet long.

The first and second quarters were treated with the granules prior to flooding. It was the intent of the experiment to find if the irrigation water will carry enough toxicant from the treated to the untreated quarter. The data obtained showed that good control of *Aedes* species could be obtained in the untreated quarters. This aspect needs further investigation since treatment of pastures in this manner provides for more economical control of pasture mosquitoes.

References Cited

Fowler, H.W. Jr., W.W. Barnes, D.W. Parish and F.H. Dowell. 1963. Recent studies on the efficacy of aerially depressed insecticides for mosquito control. Proc. N.J. Mosq. Ext. Assoc. 48: 168-177.

Lewallen, L.L., and R.F. Peters. 1966. Control of California mosquitoes resistant to organophosphorus insecticides. Mosq. News 26(3):328-330.

Mulla, M.S., H.A. Darwazeh and H. Axelrod. 1969a. Laboratory and field evaluation of new mosquito larvicides. (In press)

Mulla, M.S., H.A. Darwazeh, A.F. Geib and W.E. Westlake. 1969b. Control of pasture *Aedes* mosquitoes by dripping larvicides into flowing water with notes on residues in pasture habitat. J. Econ. Entomol. 62:365-370.

Mulla, M.S., R.L. Metcalf and A.F. Geib. 1966. Laboratory and field evaluation of new mosquito larvicides. Mosq. News 26(2): 336-342.

ACTIVITY OF NEW MOSQUITO LARVICIDES AGAINST *CULEX* AND SOME NONTARGET ORGANISMS

M.S. Mulla, H.A. Darwazeh and H. Axelrod

Department of Entomology
University of California, Riverside

In 1967 nearly 1.5 million acres of breeding sources were treated by air for mosquito control in California (Burgoyne et al., 1967). The recent increase in acreage allotment for rice production to meet the world food demand, and the completion of the California Feather River Water Project in the near future will indeed intensify the mosquito problem in California.

At the present time the most commonly used organophosphorus mosquito larvicides are ABATE®, fenthion, ethyl parathion, methyl parathion, and the newly registered insecticide Dursban®. The frequent and widespread use of chemicals for the control of *Aedes* in pastures and *Culex* and *Anopheles* species in rice fields and waterfowl marshes is a major factor contributing to the development of physiological resistance. Recent studies on irrigated pasture mosquitoes (*Aedes nigromaculis* (Ludlow) and *Aedes melanimon* Dyar) and other species indicated the presence of resistance to fenthion, methyl parathion and ethyl parathion in certain areas of Kings and Tulare counties in California (Womeldorf et al., 1968; Mulla et al., 1964). Lewallen (1966) also reported cross resistance to ABATE in those strains which are resistant to fenthion, ethyl and methyl parathion. New and effective materials are urgently needed as substitutes where resistance has become a critical problem. The following studies were conducted to find new and effective larvicides for the control of resistant as well as susceptible strains of mosquitoes.

Methods and Materials

Laboratory - In the laboratory the new compounds were evaluated against a susceptible strain of *Culex pipiens quinquefasciatus* Say. The most effective chemicals were then screened and tested against a laboratory strain of *Aedes aegypti* (L.). The method of evaluation employed is described in previous work by Mulla et al. (1966). One percent stock solution (w/v) of the technical grade of each compound was prepared in acetone, and serial dilutions of these were made as needed. Twenty 4th instar larvae were placed in 100 ml of tap water in a 4-oz wax treated dixie cup. The proper strength solution (1 ml or less) then was added to yield the effective range of concentrations. Each material was tested at least three times, two replicates per concentration. Mortality count was obtained 24 hours after treatment, and the average percent mortality was plotted against log concentration (in ppm) on log probit paper. A straight line was fitted by the eye and the LC_{50} and LC_{90} values in ppm were determined from the concentration response line.

Field - Field evaluations of the new insecticides were conducted in experimental freshwater ponds in Kern County (San Joaquin Valley) and the Coachella Valley of southern California.

A. Bear Mountain Ponds (Bakersfield, California). -
These ponds located 15 miles south of Bakersfield are 1/32 or 1/16 acre in size. The ponds were filled with water from an irrigation canal. Water depth in the ponds was maintained at 12" by flooding the ponds twice a week. Water pH was 7.5-8.0. Each dosage was replicated twice and two ponds were left as untreated checks. A known volume of emulsifiable concentrate formulations was diluted with 1,000 ml of tap water and applied with a one gallon hand sprayer. Ten dips were taken per pond prior to and 24 hours after treatment. All organisms recovered by dipping were recorded.

B. Coachella Valley Ponds (Oasis, California). -
These ponds are 20 x 20 feet in size. A wooden plank, 2 ft above water surface extends about 10 ft into each pond. The ponds are located in a highly alkaline habitat near the upper end of Salton Sea. The water for flooding these ponds comes from an artesian well. The water is carried through underground pipes into the ponds. Water level was

Table 1. Chemical descriptions and effectiveness of new insecticides against 4th instar larvae.

Compound	Chemical Description	*Culex quinquefasciatus* LC_{50}	*Culex quinquefasciatus* LC_{90}	*Aedes aegypti* LC_{50}	*Aedes aegypti* LC_{90}
C–9491	*0, 0*-dimethyl-0-2, 5-dichloro-4-iodophenyl thiophosphate	0.001	0.002	0.008	0.016
ABATE®	*0, 0, 0', 0'*-tetramethyl *0, 0'*-thiodi-p-phenylene phosphorothioate	0.001	0.002	0.005	0.009
Bay 78182	(*0*-chlorophenyl) gloxylonitrile oxime *0, 0*-diethyl phosphorothioate	0.001	0.002	0.004	0.006
Dursban®	*0, 0*-diethyl *0*-(3, 5, 6-trichloro-2-pyridyl) phosphorothioate	0.001	0.002	0.002	0.003
Ethyl parathion	*0, 0*-diethyl-*0*-*p*-nitrophenyl phosphorothioate	0.003	0.005	0.013	0.024
NIA–17370 (RD104)[1]	(5-Benzyl-3-furyl) methyl (±) Cis-trans-2-2-dimethyl-3-(2 methyl-1-propenyl) cyclopropane-1-carboxylete	0.004	0.006	0.005	0.009
AC–72499	— —	0.004	0.007	0.03	0.06
Bay 76960	— —	0.004	0.007	—	—
Bay 79330	(Diethoxythiophosphoryloximino)-2, 6-dichlorophenyl acetonitrile (alpha-isomer)	0.004	0.007	0.008	0.015
Bay 69047	*0, 0*-dimethyl-0-(4-nitro-3-isopropyl-mercaptophenyl)-thionophosphate	0.006	0.009	0.03	0.07
Bay 77488	*0, 0*-diethyl thiophosphoryl 0-alpha-cyanobenzaldoxine	0.007	0.009	0.009	0.015
Bay 78755	(diethoxythiophosphoryloximino)-2, 6-dichlorophenyl acetonitrile (β-isomer)	0.006	0.009	0.008	0.014
C–8874	*0, 0*-dimenthyl 0-2, 5-dichloro-4-iodophenyl thiophosphate	0.005	0.008	0.03	0.058
Fenthion	*0, 0*-dimenthyl 0-[4-(methylthio)-m-tolyl] phosphorothioate	0.005	0.009	—	—
AKTON® (SD-9098)	*0*-[2-chloro-1-(2, 5-dichlorophenyl) vinyl] *0, 0*-diethyl phosphorothioate	0.008	0.015	0.018	0.03
N–4446	*0*-Ethyl-S-(3-methyl-4-chlorophenyl) ethylphosphonodithioate	0.016	0.024	—	—
GS–19851	isopropyl-4, 4'-dibromobenzilate	0.015	0.026	—	—
R–10778	*0*-Ethyl-S-(3-methyl-4-chlorophenyl) ethyl phosphonodithioate	0.028	0.042	—	—
N–4988	*0*-methyl-S-(3 methyl-4- chlorophenyl) ethylphosphonodithioate	0.025	0.044	—	—
NIA–15267	— —	0.032	0.050	—	—
GC–6506	dimethyl p-(methylthio) phenyl phosphate	0.040	0.070	—	—
Bay 80833	*0*-methyl-0 (3, 4-dichlorphenyl)-methyl-thionophosphate	0.050	0.070	—	—
NIA–11637	— —	0.050	0.080	—	—
Bay 78537	2, 2-dimethyl-7-(N-methyl-N-acetyl)-carbamoyl-cumarane	0.050	0.080	—	—
Bay 62863	— —	0.070	0.100	—	—
Bay 78389	α-ethylmercapto-acetaldoxim-N-methyl-Carbamate	0.074	0.100	—	—
R–10414	*0,* Propyl-S-(2, 4-dichlorophenoxy-methyl)-ethylphosphonodithioate	0.080	0.110	—	—
Bay 69588	Methylthionophosphono-*0*-ethyl-*0* (6-hydroxychinoline)	0.080	0.120	—	—
B–11163	*0, 0*-dimethyl-*0*-(2-methoxy-4-lyanophenyl) phosphorothioate	0.084	0.115	—	—
AC–72016	— —	0.06	0.120	—	—
Neo pynamin®[1]	3, 4, 5, 6-tetrahydrophthalimidomethyl-2, 2-dimethyl-3-(2-methylpopenyl)cyclopropane-carboxylate	0.06	0.150	—	—

[1]Effective against pupae:

	LC_{50}	LC_{90}
NIA–17370	0.02	0.05
Neo pynamin®	0.4	0.5

maintained at a 12" depth by means of float valves. Water from the well had a pH of 9.0 and the average pH of water in the ponds was 9.25.

In experiments I and II emulsifiable concentrate materials were mixed with 200 ml of water and applied with a one-half gallon hand sprayer to each pond from the wooden plank. The spray was applied as a fine jet stream reaching out 10-15 feet. In experiment III and IV the emulsifiable concentrates and petroleum oils were diluted with 140 ml of water and sprayed in the above manner. For sampling mosquito larvae and non-target insects, five dips per pond were taken; two from the sides and three from the center of each pond. Water from all 5 dips was strained through a strainer provided with 125-mesh stainless steel screen. The living material in a small amount of water was transferred to 11 dram plastic vials to which 95% alcohol was added for preserving. All larval stages and pupae were counted under a dissecting microscope in the laboratory. Samples were obtained before treatment and 3, 4, 10, and 14 days after treatment.

In the remaining experiments (III - V) five dips were taken from the vegetated areas along the edges of the ponds. The five dips, again, were composited and concentrated into one sample and preserved in alcohol. Mosquito larvae and pupae and other aquatic organisms were counted in the laboratory under a dissecting microscope.

Effects of insecticides and petroleum oils on notonectids were evaluated by sweeping the ponds with a plankton net. Two dip net sweeps per pond were taken in the shady area of the plank fifteen to twenty minutes apart to allow the population to resettle. The notonectids invariably congregate in shade of the plank in the water. Notonectid samples were obtained prior to treatment and 1, 4, 14, and 21 days after treatment.

Results and Discussion

Fifty-one new materials were evaluated in the laboratory against a susceptible strain of *C. pipiens quinquefasciatus*. Thirty-one of these had LC_{90} values of 0.150 ppm or less against this species and are listed in Table 1. Eleven materials were either more effective or as effective as fenthion, a common organophosphate larvicide used for mosquito control in California. The remaining materials were less effective than fenthion. Thirteen of the most effective compounds were also tested against *A. aegypti*. Materials that had an LC_{90} higher than 0.150 ppm against *Culex* are not

Table 2. Evaluation of new insecticides against *Culex tarsalis* in freshwater ponds. (Kern County)

Chemical and formulation (%)	Dosage lb/acre	Average number of larvae/dip Pre-treatment	Post-treatment	% Mortality	Remarks[1]
Bay 77488 EC 50	0.01	5.1	1.1	78	P, DBA B DFN, MFN, DBL alive
Bay 77488 EC 50	0.05	3.7	0.5	87	B, P, DBL, DBA alive
Bay 77488 EC 50	0.10	2.0	0.2	90	P, B, MFN, DFN DBL, C alive
AKTON® EC 25	0.01	3.3	1.5	54	B, DFN, MFN, DBL alive
AKTON® EC 25	0.05	1.6	0.2	88	DBA, P, DFN, C alive
AKTON® EC 25	0.10	1.4	0.1	93	P, DBL, B, DFN alive
Bay 69047 EC 25	0.01	4.6	1.4	70	P, B, DBA alive
Bay 69047 EC 25	0.05	4.3	0	100	B, DFN, P, DBL alive
Bay 69047 EC 25	0.10	2.1	0.1	95	DBL, C, B alive
–	Check	3.0	3.6	0	

[1]P – Mosquito pupae
B – Belastomatids
DBA – Diving beetle adult
DBL – Diving beetle larvae
C – Corixids
MFN – Mayfly naiads
DFN – Dragonfly naiads

Table 3. Evaluation of new insecticides against *Culex tarsalis* in Oasis Water Ponds. (Ph 9–9.5, March–April 1968)

Chemical & formulation (%)	Dosage lb/acre	Average number of larvae and pupae/5-dip sample: Pre–treatment 1-2	3-4	P	Post–treatment (days) 3: 1-2	3-4	P	7: 1-2	3-4	P	10: 1-2	3-4	P	14: 1-2	3-4	P
Experiment I																
Bay 79330 EC 50	0.01	9	27	5	15	25	4	14	9	5						
	0.05	25	34	9	3	6	4	4	2	2	11	0	1	70	19	0
	0.10	10	26	3	6	2	4	8	0	0	26	4	4	51	20	0
	0.25	7	47	63	3	0	2	17	0	0	2	0	1	26	0	0
C–9491 EC 33	0.005	7	13	2	4	1	6	16	1	1	3	3	1	21	10	2
	0.01	7	19	13	4	0	6	14	0	0	25	5	0	91	9	0
	0.05	13	14	4	1	0	1	12	0	0	23	2	0	60	13	0
Bay 78755 EC 50	0.01	9	9	4	5	2	7	4	7	1	5	2	1	9	7	2
	0.05	22	18	4	16	1	5	8	0	0	8	1	2	11	10	0
	0.10	11	28	4	11	0	3	33	0	1	21	10	0	38	20	0
	Check	9	30	9	18	25	7	16	48	8	14	3	4	23	8	2
Experiment II																
NIA–17370 EC 25	0.10	27	22	36	9	15	26	132	9	4				36	31	6
	0.25	26	7	11	11	1	1	47	2	1				97	23	1
	0.50	74	46	14	6	2	4	71	2	2				103	43	1
Carbofuran (2%) gran	0.10	29	84	13	21	52	11	69	17	9				177	27	3
	0.25	14	27	5	5	3	6	33	3	4				57	14	0
	Check	6	9	1	14	4	4	23	8	2				20	7	0

Table 4. Effectiveness of new insecticides against *Culex tarsalis* studied in Oasis Ponds (March–April 1968).

Chemical and formulation	Dosage lb/acre	Avg. number of larvae/dip before and after treatment. Pre–treat	1	7	14	21
Experiment III						
Bay 69047 EC 25	0.01	16	3	5	5	–
	0.05	6	0	4	14	–
	0.10	22	0	2	12	–
Bay 77488 EC 50	0.01	5	1	3	7	–
	0.05	9	2	6	14	–
	0.10	19	0	18	–	15
Check	–	17	20	18	–	–
Experiment IV						
Bay 78182 EC 25	0.005	11	4	4	9	–
	0.01	16	2	15	15	–
	0.05	19	0	21	14	–
	0.10	14	0	0	14	–
Bay 78755 EC 50	0.005	12	10	7	7	6
	0.01	9	3	4	3	7
	0.05	10	0	3	12	–
	0.10	7	0	4	10	–
GS–6506 EC 50	0.05	4	0	0	0	2
	0.10	31	0	0	3	6
	0.25	15	0	0	5	8

Chemical and formulation	Dosage lb/acre	Avg. number of larvae/dip before and after treatment. Pre–treat	1	7	14	21
Experiment IV con't.						
SD–9098 (AKTON®) EC 25	0.005	10	2	6	–	–
	0.01	13	0	0	1	–
	0.05	8	1	0	1	–
	0.10	7	0	0	0	0
Neo pynamin® EC 20 (W/Synergist)	0.05	26	8	5	–	–
	0.10	35	4	30	–	–
	0.25	8	0	1	4	–
	0.50	5	0	0	2	0
Neo pynamin® EC 20 (W/O synergist)	0.05	14	8	3	7	5
	0.10	11	3	–	–	–
	0.25	24	1	2	5	6
	0.50	15	3	10	10	1
Check	–	12	19	6	4	7

included in Table 1. They were:

AC-72232, C-8353, C-8514, C-9643, C-10015, C-10573, CP-49674, CP-53926, Dupont 1179, 1642, GC-9879, GS-10128, GS-13798, Lanate, N-3727, N-4543, NIA-10559, NIA-10586, R-3422, R-11163, SD-9129, UC-21427, UC-22463 and UC-25074.

Three organic phosphate insecticides were evaluated in freshwater ponds near Bakersfield, California against larvae of *Culex tarsalis* Coq. (Table 2). The three materials Bay 69047, Bay 77488 and AKTON® were quite effective, the former compound being the most effective of the three. None of the materials at the indicated rates showed high acute toxicity to the nontarget organisms shown in Table 2.

Several new materials were evaluated in freshwater ponds established near Oasis in the Coachella Valley of southern California. In experiments I and II (Table 3) young larvae (1st and 2nd stage), older larvae (3rd and 4th stage) and pupae were counted.

In these studies absence of 3rd-4th stage larvae and pupae is a criterion for control. Oviposition in the ponds was heavy and young larvae (especially 1st stage) were often found in the treated ponds. Long exposure to the insecticidal residues or predation by natural enemies eliminated the larvae before reaching the third, fourth or pupal stage.

Bay 79330 gave control at 0.25 lb/acre rate but not at lower rates. C-9491 essentially gave the same level of control at the two higher (0.01 and 0.05 lb/acre) rates. It will be pointless to apply this chemical at the higher rate, because of its possible hazards to nontarget organisms. Bay 78755 also produced similar reduction at the two higher rates (0.05 and 0.1 lb/acre). NIA-17370 (related to pyrethrins) produced moderate control of larvae and pupae initially but the mosquito population increased soon after treatment. Carbofuran applied as granules did not yield sufficient control at the administered rates.

In experiments III and IV, 6 organophosphate insecticides and Neo pynamin® were evaluated. Here, the total number of larvae consisting of all stages were counted (Table 4). Bay 69047 and Bay 77488 controlled mosquitoes for less than a week at the highest rate of 0.1 lb/acre. Larval populations increased considerably two weeks after treatment. Bay 78182 and 78755 also yielded a similar level of control as the above two materials. GC-6506 gave excellent control for about two weeks at all rates used. AKTON (SD-9098) yielded almost complete control at the three higher rates of 0.01, 0.05 and 0.10 lb/acre. This material although having low activity in the laboratory holds a good promise in field control programs. Neo pynamin with synergist added proved more effective than without synergist, giving good control at 0.5 lb/acre of actual material.

Three petroleum oils Toxisol FLC (Fluid Light Cycle, a paraffinic oil), Toxisol TB (an isoparaffinic oil) both furnished by the Atlantic-Richfield Corporation and Flit® MLO (Mosquito Larvicidal Oil) furnished by Esso Engineering Research Corporation, were evaluated in the ponds against *C. tarsalis.* Young and old larvae and pupae were counted (Table 5).

Toxisol FLC gave good control for a week at 2 and 4 gallons per acre. Toxisol TB yielded essentially the same results. Flit MLO, gave complete control at 2 and 4 gallons per acre for 3 weeks after which the experiment was terminated. At the lowest rate Flit MLO did not yield a high level of control.

Nontarget Organisms - The numbers of most of the naiads of anisopteran Odonata sampled were small. It is difficult to draw any definitive conclusions as to the effects of the insecticides used on these organisms. However, certain trends are obvious which are worth noting.

The aeshnid (*Anax* sp.) naiads were not markedly affected by any of the insecticides except by GC-6506 for a short period of time. Similarly, libellulid naiads were not affected.

Table 5. Control of *Culex tarsalis* with petroleum hydrocarbons evaluated in breeding ponds.[1] (Oasis, California)

Petroleum oil	Gal/ acre	Pre–treatment 1-2	Pre–treatment 3-4	Pre–treatment P	Post–treatment (days) 2: 1-2	2: 3-4	2: P	7: 1-2	7: 3-4	7: P	14: 1-2	14: 3-4	14: P	21: 1-2	21: 3-4	21: P
Toxisol	0.5	12	3	0	8	3	1	9	2	0	18	5	0	–	–	–
FLC	1.0	3	3	0	1	1	0	4	2	0	10	3	0	–	–	–
	2.0	11	2	0	0	1	0	4	0	0	13	6	0	–	–	–
	4.0	10	4	1	0	1	0	0	0	0	6	6	0	–	–	–
Toxisol	1.0	2	4	1	2	3	2	2	0	0	5	2	0	–	–	–
TB	2.0	5	4	2	2	1	0	3	1	1	5	3	0	–	–	–
	4.0	4	5	1	0	0	0	1	0	0	0	1	0	4	2	0
Flit®	1.0	10	2	0	6	2	0	4	0	0	6	2	0	12	2	0
(MLO)	2.0	7	2	0	1	0	0	0	0	0	0	0	0	1	0	0
	4.0	5	3	1	1	0	0	0	0	0	0	0	0	1	0	0
Check	–	6	3	0	6	1	0	9	1	0	8	4	0	7	6	0

Average number of larvae and pupae/dip.

[1]Toxisol FLC and TB contained (1%) Atlox 1256, a nonionic surfactant: Flit® MLO also contained (1%) of an unknown additive.

Table 6. Effects of various new mosquito larvicides on naiads of damselflies and mayflies.

Material and formulation (%)	lb/acre	Total number of naiads per 5 dips before and days after treatment: Coenagrionidae pre-	1	7	14	21	Baetidae pre-	1	7	14	21
Bay 69047											
EC 25	0.01	5	9	3	1	5	44	0*	10	19	–
	0.05	8	2	3	2	–	13	0*	0*	14	–
	0.10	1	2	0	0	–	35	0*	0*	3	–
Bay 77488											
EC 50	0.01	6	–	6	13	0	14	–	3	59	–
	0.05	16	–	12	9	5	5	–	0*	86	–
	0.10	7	–	4	–	1	8	–	1	–	80
Bay 78182											
EC 25	0.005	12	8	27	6	–	11	3	8	7	–
	0.01	9	2	12	16	–	16	0	5	17	–
	0.05	4	4	2	–	–	22	8	1	–	–
	0.10	2	0*	0	0	–	14	1*	0	1	
Bay 78755											
EC 50	0.005	0	4	1	0	–	3	0	4	10	
	0.01	6	10	7	3	–	7	11	6	2	–
	0.05	23	–	6	20	2	32	–	0*	29	1
	0.10	2	–	4	2	1	8	–	3	15	2
Check	–	6	12	15	2	–	25	–	78	47	–
GC–6506											
EC 50	0.05	14	2*	5	2	4	8	0*	0*	4	18
	0.10	24	0*	2	2	8	82	0*	5	41	145
	0.25	16	2*	0*	0	0	17	0*	0*	15	53
AKTON®											
EC 25	0.01	15	7	1	3	1	25	23	0*	2	9
	0.05	9	3	1	0*	0*	71	0*	0*	0*	0*
	0.10	59	4*	0*	0*	0	13	0*	0*	0*	0
Neo pynamin® EC 20											
(W/Synergist)	0.10	8	4	6	3	–	69	98	79	80	–
	0.25	9	3	5	4	–	26	4	181	246	–
	0.50	7	1	2	7	–	43	22	4	25	–
Neo pynamin® EC 20											
(W/O syn)	0.10	15	7	1	3	–	25	23	0	2	–
	0.25	10	6	3	3	–	56	79	80	116	–
	0.50	7	1	0	21	–	208	800	272	450	–
Check	–	2	14	3	2	10	47	71	56	62	110

*Marked mortality and/or lack of recovery.

These naiads are generally benthic, browsing at the bottom of the ponds.

The damselfly naiads (Coenagrionidae) were sampled in relatively larger numbers (Table 6). Bay 78182 at 0.1 lb/acre markedly affected these naiads. Similarly, GC-6506 caused considerable mortality of these naiads. AKTON at the two higher rates (0.05 and 0.1 lb/acre) also affected them. The recovery of these naiads was slow and did not occur during the duration of the studies for 3 weeks after treatment.

Mayfly naiads (Baetidae) were the most susceptible non-target insects studied. They were eliminated by all dosages of Bay 69047 tested but the recovery was rapid, and the naiads reappeared 3 weeks after treatment. Although Bay 77488 caused marked mortality of mayfly naiads, they repopulated the treated ponds within two weeks after treatment. The same trend was obvious for Bay 78182 and Bay 78755. AKTON completely eliminated the naiads and the population did not recover during the 3-week post-treatment period except at the lower rate of 0.01 lb/acre. Neopynamin had no marked effect on the mayfly naiads.

Notonectids (mostly *Boenoa* and *Notonecta* spp.) were not affected by Bay 69047 treatments (Table 7). Bay 77488 affected notonectid populations for a short period but recovery was good within a week after treatment. Bay 78182 was quite toxic to notonectids at the two higher rates and recovery was slow. Bay 78755 did not affect the notonectids, nor did GC-6506. AKTON at the three highest rates affected notonectids and recovery at the highest rate (0.10 lb/acre) did not occur during the 3-week study period. Neo pynamin did not affect notonectids to any marked degree.

Table 7. Toxicity of various new insecticides against notonectids in fresh water ponds.[1] (Oasis, California)

Material & formulation (%)	lb/acre	Avg. number notonectids/sweep dip before and days after treatment: pre-treat	1	7	14	21
Bay 69047 EC 25	0.01	9.5	7.0	4.0	18.0	–
	0.05	10.5	7.0	8.5	15.0	–
	0.10	6.0	2.0	5.5	15.0	–
Bay 77488 EC 50	0.01	4.0	39.0	8.0	10.5	–
	0.05	26.5	1.0	2.0[2]	5.0	–
	0.10	2.5	1.0	5.0	–	–
Check	–	11.5	6.0	10.5	10.0	–
Bay 78182 EC 25	0.005	22.5	16.0	3.5[2]	15.0	–
	0.01	5.5	18.0	5.0	11.5	–
	0.05	20.0	0.0	0.0	2.0	7.0
	0.10	16.5	0.0	0.0	1.0	2.0
Bay 78755 EC 50	0.005	15.0	11.5	2.5	7.5	5.0
	0.01	15.0	13.5	10.0	43.5	23.5
	0.05	1.0	9.0	3.5	11.5	–
	0.10	4.0	4.0	8.0	15.5	–
GC–6506 EC 50	0.05	12.0	24.5	16.0	43.5	60.5
	0.10	18.5	15.0	22.5	36.5	38.5
	0.25	11.5	17.5	9.5	43.0	18.0

Material & formulation (%)	lb/acre	Avg. number notonectids/sweep dip before and days after treatment: pre-treat	1	7	14	21
AKTON® EC 25	0.005	50.0	8.0	10.0	8.0	–
	0.01	10.5	3.1	1.0	2.5	4.5
	0.05	13.5	0.2	0.0	1.0	1.0
	0.10	10.5	0.0	0.0	0.0	0.0
Neo pynamin® EC 20 (W/Synergist)	0.05	20.0	9.0	–	–	–
	0.10	8.0	9.0	–	–	–
	0.25	9.5	17.5	7.5	32.0	31
	0.50	16.0	3.0	26.0	18.0	–
Neo pynamin® EC 20 (W/O synergist)	0.05	31.5	22.5	19.0	55.5	31.5
	0.10	13.5	23.5	4.0	1.0	0.5
	0.25	18.0	11.5	24.0	44.0	–
	0.50	26.0	6.5	18.0	24.0	–
Check	–	10.0	10.0	11.5	25.5	–

[1]Over 90% of the notonectids are small nektonic form. The larger ones usually are benthic and not many were recovered by the sampling technique.

[2]Shady.

Table 8. Effect of petroleum mosquito larvicidal oils on some immature nontarget insects in experimental breeding ponds.[1] (Oasis, California)

		Total number naiads/10 dips days after treatment[2]													
		Aeshnidae				Coenagrionidae				Baetidae					
Petroleum oil	Gal/acre	Pre-	1	7	14	Pre-	1	7	14	Pre-	1	7	14	21
Toxisol FLC	0.5	30	37	6	13	2	17	9	17	22	59	49	109	–
	1.0	11	12	2	8	3	3	26	35	27	36	26	126	–
	2.0	20	10	3	17	2	5	12	10	53	35	1*	51	–
	4.0	10	–	1	4	2	–	6	12	17	–	2*	8	80
Toxisol TB	1.0	12	–	3	3	7	–	18	29	6	–	11	46	–
	2.0	38	–	4	3	10	–	23	18	15	–	25	13	–
	4.0	22	–	6	1	11	–	20	12	21	–	30	7	78
Flit® MLO	1.0	22	24	11	12	5	4	20	32	54	71	15*	44	–
	2.0	35	23	14	10	4	7	19	18	26	66	6*	7*	36
	4.0	31	31	6	2	5	11	8	29	31	23	5*	1*	12
Check	–	26	29	8	7	5	15	16	18	33	53	67	70	113

[1]Toxisol FLC and TB were added 1% Atlox 1256 a nonionic surfactant. Flit® MLO also had 1% of an unknown additive.

[2]Each treatment replicated twice and 5 dips (sampling approximately 200-300 ml of water each) were taken in vegetated edges of each pond.

*Marked mortality and/or lack of recovery.

Table 9. Toxicity of various petroleum hydrocarbon mosquito larvicides against notonectid populations in experimental breeding ponds (Oasis, California).

		Average number/dip sweep before and days after treatment				
Petroleum Oil	gals/ acre	pre-treat	1	7	14	21
Toxisol FLC[1]	0.5	8.6	7.5	6.0	25.0	9.0
	1.0	28.0	16.5	7.0	12.0	3.5[3]
	2.0	19.0	2.2	2.0	6.0	–
	4.0	42.0	2.0	1.5	2.5	8.0
Toxisol TB[1]	1.0	35.0	20.0	11.5	2.5	–
	2.0	25.0	12.0	7.0	15.0	–
	4.0	26.0	2.0	3.0	9.0	9.0
Flit® MLO	1.0	19.0	2.5	7.0	14.0	3.0
	2.0	18.0	0.0	3.5	7.5	2.0
	4.0	18.0	0.0	1.0	2.0	4.2[3]
Check[2]	–	10.0	14.0	4.0	10.0	10.0

[1]Containing 1% Atlox 1256 a nonionic surfactant. Flit® MLO had 1% unknown additive.

[2]Replicated 4 times, all other treatments replicated 2 times.

[3]Shady – population more spread out.

The three petroleum oils studied earlier against mosquitoes did not influence any of the odonatan naiads studied (Table 8). The mayfly naiads, however, were adversely affected by the two higher rates of Toxisol FLC and all three rates of Flit MLO. Recovery occurred within 3 weeks after treatment.

Notonectids were markedly affected by the 2 and 4 gallon rates of Toxisol FLC and 4-gallon rate of Toxisol TB (Table 9). Flit MLO proved highly toxic to notonectids at all three rates of application. Slight recovery occurred within 2 weeks after application.

It should be pointed out that the studies dealing with the effects of mosquito control agents on nontarget organisms are preliminary in nature. Since they show certain interesting relationships the results are presented here. Those materials which affect nontarget population density directly or indirectly could pose a serious hazard to the nontarget organisms. Under normal mosquito control operations, treatments will be made semi-monthly. Under such a regime of treatment programs the nontarget organisms when affected by a given control agent will have no opportunity to rebound. Therefore attempts should be made to use materials that pose low level of hazards at mosquito larvicidal rates to the nontarget aquatic organisms.

References Cited

Burgoyne, W.E., N.B. Akesson, T.D. Mulhern and K. Phillips. 1967. The present status of low volume (LV) air sprays for California mosquito control. Mosq. News 27(3):398-407.

Lewallen, L.L. and R.F. Peters. 1966. Control of California mosquitoes resistant to organophosphorus insecticides. Mosq. News 26(3):328-330.

Mulla, M.S., R.L. Metcalf and A.F. Geib. 1966. Laboratory and field evaluation of new mosquito larvicides. Mosq. News 26 (2):236-242.

Mulla, M.S., R.L. Metcalf and G. Kats. 1964. Evaluation of new mosquito larvicides, with notes on resistant strains. Mosq. News 24(3):312-319.

Womeldorf, Don J., Patricia A. Gillies, and Kathleen E. White. 1968. Present status of insecticide resistance in California mosquito larvae. Proc. Calif. Mosq. Control Assoc. 36:81-84.

THE IMPACT OF DURSBAN® ON POND ECOSYSTEMS

Stuart H. Hurlbert

Department of Entomology
University of California, Riverside

ABSTRACT

The effects of Dursban® on the phytoplankton and invertebrate populations were studied in an experiment where Dursban was applied to small ponds three times at biweekly intervals. Four ponds were kept as controls, four were treated at 0.025 lbs/acre and four were treated at 0.25 lbs/acre. At both rates the total insect and total crustacean populations were greatly reduced. Some invertebrates (e.g., beetles) were much less susceptible to Dursban than were others (e.g., mayflies, most crustaceans), and larval stages were more susceptible than were adults. The lower rate of Dursban appeared to stimulate the hatching of the eggs of tadpole shrimp (*Triops longicaudatus*). Thus, the use of Dursban to control mosquitoes in tadpole shrimp-infested rice fields could increase shrimp damage to rice seedlings. Phytoplankton populations, including diatoms and blue-green algae, increased dramatically in treated ponds. In control ponds phytoplankton populations were maintained at comparatively low levels by the grazing of crustaceans. Similar increases in phytoplankton must occur when any insecticide is used in an aquatic habitat, as all insecticides probably are highly toxic to planktonic crustaceans. The induction of blue-green algal blooms by insecticides is significant in that such blooms can be toxic to humans and livestock, can cause fish kills, and generally diminish water quality from the viewpoint of domestic and recreational use.

ANOPHELES MOSQUITO CONTROL PROBLEMS IN THE NORTHERN SACRAMENTO VALLEY

William Hazeltine and Elmer Kingsford

Butte County Mosquito Abatement District
Oroville, California

A review of the literature on rice field mosquitoes in the Sacramento Valley, and discussions about *Anopheles* control with long-time residents, rapidly point up two things. First, the rice field mosquitoes have been the subject of a large amount of work. Second, the severity of the *Anopheles* part of the rice field mosquito complex seems to have persisted for the past 20 years with varying amounts of control success.

We want to look particularly at control problems without getting involved in all the details of a historical literature review and consideration of the extensive literature on *Anopheles* ecology as a broad subject. Our intention is to look specifically at the controls available today and plans for work in the future.

We know from our own experience that *Anopheles* problems exist in the valley parts of Butte, Colusa, Glenn, Sutter and Yuba counties, where about 75% of the 1968 rice acreage was located. We suspect the problem exists in most of the areas which are suitable for rice production, but perhaps at less severe levels because of fewer acres of rice, or perhaps the more southerly locations.

Current *Anopheles* Control Work

At the present time, the biological control work of Dr. Washino (1968 & previous) at Davis is about the only bright spot in the *Anopheles* picture. There are other university biological control programs, but this is the only one we know about at the present time which is rice field and control oriented.

Last year, the "Colusa experiment" (Whitesell, 1968) and the Sutter-Yuba District tests were the only field programs on *A. freeborni* chemical control research or investigation that we know about. It is our understanding that the federal funds are gone for continuation of the "Colusa experiment," which leaves only local district programs for 1969. In addition, ultra low volume may be seriously restricted due to its potential damage to painted surfaces.

The mosquito abatement districts in the northern Sacramento Valley area who have the capability are committed to the proposition that local investigations must continue and all the districts agree that the extent and severity of the problem must be spelled out clearly and in detail so that proper support can be enlisted from all areas. As an example, in 1968 we sprayed 90,980 total acres of rice in Butte County, which has only 77,000 acres of allotment. We tried to hit the rice early to reduce the *Culex* with its potential of viral encephalitis, and apparently we were successful. However, in mid-August dusk bite counts of *Anopheles* were at 75 per minute, and the season got worse as it progressed. In areas where we tried to control

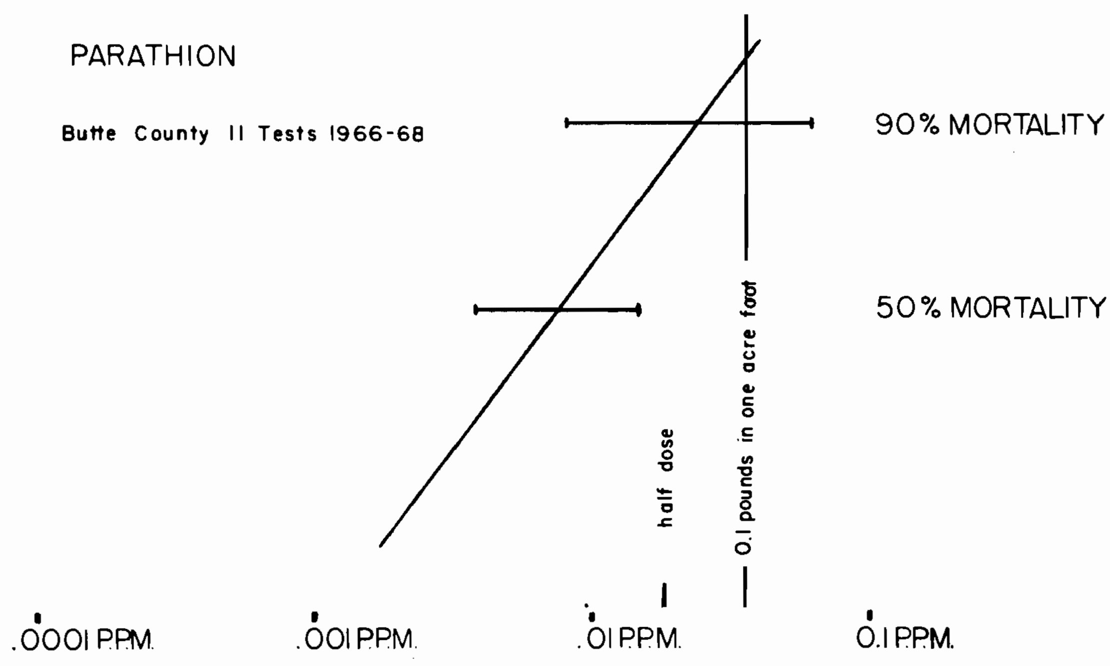


Figure 1. Mortality of *Anopheles freeborni* with parathion, 1966 and 1968, Butte County.

Anopheles, light trap counts were as high as 10,000 adults per trap week.

When we compare the extent of the *Anopheles* control problems to the total effort to develop a reasonable control technology, the conclusion seems to be that the problem is not getting proper attention. We feel that if an epidemic of malaria occurred next year, we do not have enough know-how to mount a reasonable program of predictable success which we could afford.

Current Chemical Control Materials

Parathion is the only material generally used on rice for *Anopheles* and *Culex*. It seems to be very effective on *Culex* at the 1/10 pound per acre rate. Apparently poor control of *Anopheles* in 1968 prompted a critical look at laboratory data on effectiveness of various materials on field collected larvae. A review of weather data shows a cool period in mid-summer, and the work of Bailey and Gieke (1968) offers an explanation which could account for more mosquitoes through lowering of water temperature early in the season. The conclusion that control was not satisfactory is based on subjective observation by district personnel and taxpayers, and the dose mortality data we present is our own and that from other districts. Larval dipping records are not considered, except those from the "Colusa experiment," because of the problems of finding the larvae in a rice field.

Figure 1 represents a summary of data on parathion mortality on *A. freeborni* Aitken and is a composite of eleven different tests in 1966 and 1968 on Butte County mosquitoes. The angled line represents the average 24-hour dose mortality values. The horizontal bars represent the extremes of all tests at the 50 and 90% mortality levels. The vertical line depicts the theoretical dose for 1/10 pound per acre of water, 1-foot deep, and the short line half the dose. We saw no evidence of change in the mortality regressions from 1966 to 1968. Our graphic presentation is based on simple extremes and a subjective average. It seemed more convenient than eleven separate lines.

Figure 2 represents a composite of 11 tests on *A. freeborni* from Northern California, mostly from Sutter and Yuba counties where rice spray has been very limited. Compared to Butte County where parathion rice spray has been practiced since 1961, the difference in LC_{50} is 2 times. We do not feel that there is sufficient evidence to conclude that resistance or vigor tolerance is the cause; other things could account for the difference and there was no apparent difference between the 1966 and 1968 data from Butte County.

As a unit, the parathion data suggest that this compound is not a particularly good *A. freeborni* killing chemical, or at least it is not particularly good at the 1/10 pound per acre rate, under our conditions of a foot of water depth and thick rice plant growth which prevents penetration of the spray to the water.

Dursban® data on *A. freeborni* are presented in Figure 3 with the expected dose from 1/20 pound per acre in 1-foot water and the half dose. Compared to the data of Womeldorf and Gillies (1968) Burgoyne, Whitesell and Akesson (1968), and Lembright (1968) these data seem consistent with the control obtained with like doses in the "Colusa experiment" and give support to our consideration of laboratory data for field efficacy predictions. Water depth in Butte County is usually maintained near the 1-foot level, while that in the "Colusa experiment" was reported as less.

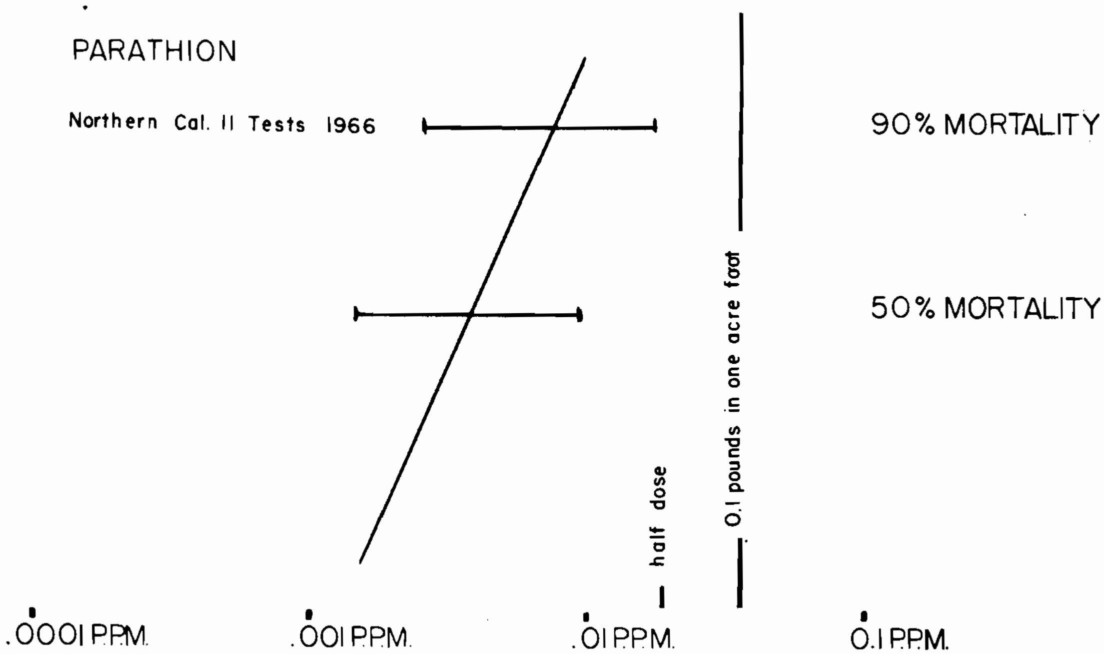


Figure 2. Mortality of *Anopheles freeborni* with parathion, 1966 northern California.

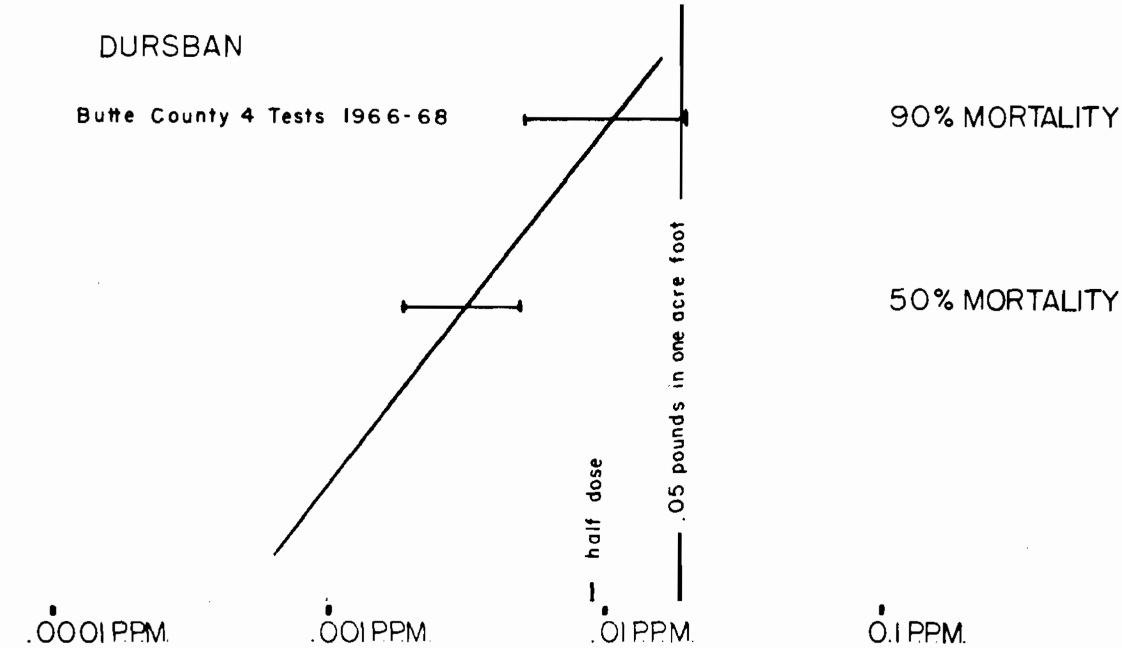


Figure 3. Mortality of *Anopheles freeborni* with Dursban, 1966 and 1968, Butte County.

Baytex® data are shown in Figure 4 and are a composite of 5 tests. At the 1/10 pound per acre rate, this compound appears to be comparable to Dursban at 1/20 pound per acre in its effect on *freeborni*.

Looking at these compounds as representing candidates which are currently registered or anticipated to be registered on rice in the near future for *freeborni* control, our conclusion is that we do not have a satisfactory material which can be used effectively and still be reasonable in cost. ABATE® is roughly 1/5 and malathion 1/10 as active as parathion, and neither one is seriously considered for this use. Chemagro's compound Bay 77488 looks about 10 times as active as parathion on *freeborni*, but information is limited and not substantiated with field tests.

In the absence of resistance, the only relief we can see is to try to get permission for an increased dose of parathion, in the range of 2/10 pound per acre; its residue tolerance is established and adequate for this rate, and cost is within reason.

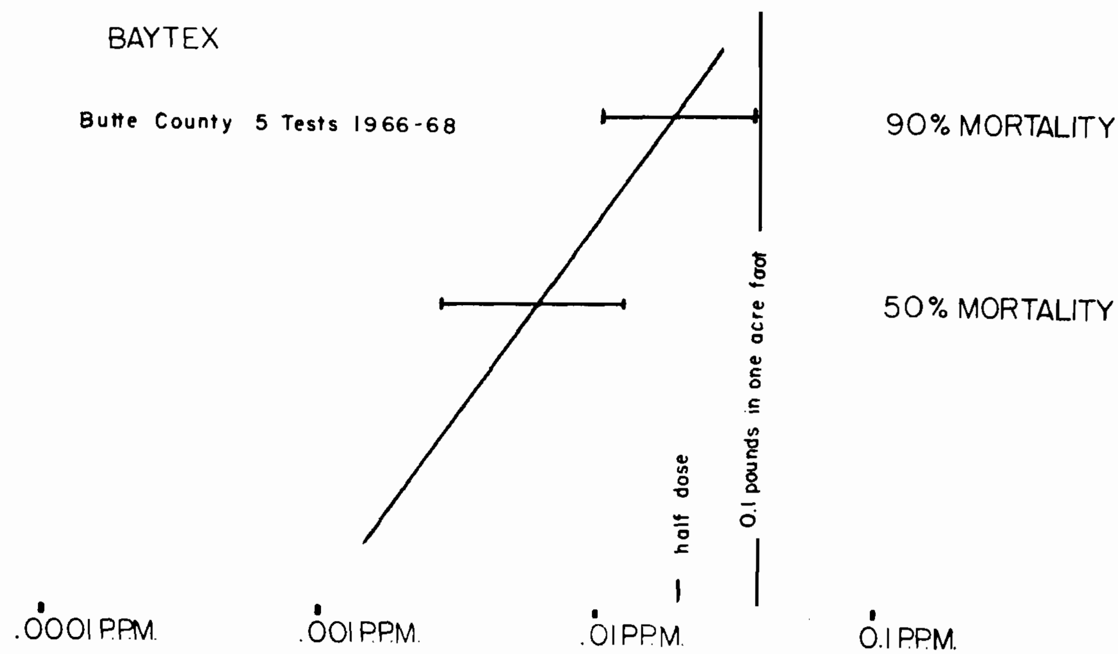


Figure 4. Mortality of *Anopheles freeborni* with Baytex, 1966, northern California.

Suggestions

We have definite ideas on what is needed in the area of *Anopheles* control investigations. While these are not necessarily in order of priority, they are all important and are offered so that anyone who wants to work on the problem will not have a shortage of suggestions. We propose to:

1. Promote the availability of new chemical compounds through screening of compounds on *Anopheles freeborni*. We may be in our present predicament partly because of extrapolation of data from one species to another. We also recognize the need for field tests when good candidate compounds are available.
2. Help with registration of compounds through use data, residue samples and encouragement.
3. Try to make methyl and/or ethyl parathion work, through better systems to get the insecticide to the insects, and work for clearance of higher doses through tests on birds and fish, as well as field tests on mosquitoes.
4. Do more work on ultra low volume application, in an attempt to understand and use this method without property damage.
5. Look critically at adult control as an additional tool, particularly by use of new methods, formulations, timing and insecticides.
6. Improve field sampling techniques, using experienced men to show others how to find larvae, and thereby be able to accurately assess the results of field tests.
7. Work for and encourage continued meaningful research on using and understanding all methods of control, such as fish, algae, insect predators, diseases, slow release granules, ultra low volume and anything else which offers promise.
8. Hope that, through explanation of the problem, others will realize the severity of it and generate an interest in *Anopheles* particularly the urgent, immediate need for an effective control chemical.

Summary

Anopheles freeborni is a persistent pest which reproduces well in mid-to late season in rice fields of the northern Sacramento Valley. At the present time, we do not have an effective control material or method available. While there is limited current support for work on *Anopheles*, we feel that the severity of the problem demands more effort.

References Cited

Bailey, S.F., and P.A. Gieke. 1968. A study of the effect of water temperature on rice field mosquito development. Proc. Calif. Mosq. Control Assoc. 36:53-61.

Burgoyne, W.E., K.G. Whitesell and N.M. Akesson. 1968. Entomological evaluation within the Colusa project. Down to Earth 24(2):13-15.

Lembright, H.W. 1968. Dosage studies with low volume applications of Dursban insecticide. Down to Earth 24(2):16-17.

Washino, R.K. 1968. Predator-prey studies in relation to an integrated mosquito control program. A Progress Report. Proc. Calif. Mosq. Control Assoc. 26:33-34.

Whitesell, K.G. 1968. The mosquito problem in Colusa County, California. Down to Earth 24(2):11-12.

Womeldorf, D.J. and P.A. Gillies. 1968. Bioassay determination of aircraft swaths and rice – canopy penetration by low volume insecticidal sprays at Colusa, California. Down to Earth 24 (2):23-27.

OBSERVATIONS ON THE OCCURRENCE OF *AEDES SIERRENSIS* (LUDLOW) IN RED FIR STUMPS IN A SIERRAN CONIFER FOREST

Earl W. Mortenson

Bureau of Vector Control & Solid Waste Management
Berkeley, California

ABSTRACT

Mosquito complaints caused by *Aedes sierrensis* (Ludlow) were investigated in the Huntington Lake area of Fresno County. A survey of the area indicated the main source of these mosquitoes was water that had accumulated in holes in the tops of red fir *(Abies magnifica)* stumps. Additional observations made in the nearby Tamarack Ridge area, elevation 7800 feet, during the summers of 1963-65 indicated that many of the mature red fir trees, which were logged in the early 1950's, had holes in the stumps caused by a central portion of the stump being pulled out during the time the trees were cut. Depth of these holes varied from 8 to 15 inches.

The first water to collect in the stump holes comes from the winter accumulation of snow that melts during the spring thaw. This effects the initial hatch of *Aedes sierrensis* eggs. Additional generations are produced as these holes periodically fill with rain water from thunder storms that occur about every ten days at this elevation.

PATTERN OF DISPERSION OF THE PASTURE MOSQUITO *AEDES NIGROMACULIS* (LUDLOW) LARVAE IN AN EXPERIMENTAL PLOT

Takeshi Miura

Mosquito Control Research Laboratory
University of California, Fresno

Operators of the mosquito abatement districts know, through experience, where they can find mosquito larvae in the field. Operators have learned that individuals in a mosquito population tend to disperse into clumped patterns in their natural breeding site. Such intrapopulation dispersion has been studied by many investigators. They have proposed a number of mathematical models to express patterns of clumping and have suggested methods that can be used to

Table 1. Frequency distribution of larvae based on a single dip at 100 stations in the test plot.

No. of Larvae/Dip	1st Instar	2nd Instar	3rd Instar	4th Instar
0	39	31	36	49
1	22	12	24	18
2	6	5	11	9
3	4	6	5	3
4	0	5	5	4
5	3	2	6	2
6	2	1	0	3
7	3	3	1	3
8	2	4	2	2
9	2	3	2	1
10	0	2	0	0
11	1	2	0	0
12	1	1	1	0
13	1	2	0	1
14	0	2	1	0
15	1	0	0	2
16	1	1	0	2
17	0	1	0	1
18	1	3	1	
19	0	2	1	
20	1	0	0	
21	1	2	0	
22	0	1	0	
23	0	2	0	
24	0	0	0	
25	0	0	0	
26	1	0	0	
27	1	0	1	
28	1	0	0	
29	0	0	1	
30	0	0	1	
32	0	1	0	
34	1	0	0	
37	0	0	0	
38	0	0	0	
39	0	1	0	
43	0	0	0	
44	0	0	1	
45	1	0		
46	1	1		
54	0	0		
55	0	1		
58	0	1		
60	0	1		
71	1	0		
88	0	1		
191	1			
219	1			

determine the degree of clumping (Anscombe, 1949; Wadley, 1950; Utida et al., 1952; Pielou, 1957; Bliss and Owen, 1958; Water, 1959; Water and Henson, 1959).

The pasture mosquito, *Aedes nigromaculis* (Ludlow), is one of the most annoying pest mosquitoes occurring in the Central Valley of California; it is a severe biter, develops in large numbers in irrigated pastures and also has developed resistance to many insecticides.

Mosquito control, especially of pasture mosquitoes, is largely dependent upon aircraft application of larvicides to breeding sites, therefore accurate information on the density as well as pattern of dispersion of the larvae are important.

The purpose of this study was to examine the pattern of dispersion of *A. nigromaculis* larvae in a natural breeding site.

Methods and Materials

About one acre of the Kaweah-Delta Gun Club property, in the vicinity of Traver, California, was used as an experimental pasture (Lewallen, 1963). The pasture was subdivided into 30 plots; 15 plots were on the northwest side of the irrigation ditch and another 15 plots were on the southeast side. The plots were rectangular, measuring 10 x 136 feet (1/32 acre), and consisted of individual irrigation basins with shore margins on all sides. Originally, the plots had been seeded with a pasture mixture - clover, rye grass, and orchard grass; however, bermuda grass, sedges, and other weeds were predominant at the time of this study.

Larvae were collected with a white-enameled dipper having a 3-foot extended handle. The dipper was 4 inches in diameter and 2.5 inches deep. The density and distribution of larvae were examined by dipping at 100 stations on each plot. The sampling stations were arranged in a grid pattern (4x25 stations). A standardized dipping technique was used at each sample station in order to obtain unbiased data.

Results and Discussion

The data on frequency distributions of each instar, based on a single sample at each of 100 stations, indicate that individual larvae were not dispersed at random in the plots, but rather in a clumped pattern (Table 1). Degrees of clumping were dependent upon the age of the larvae; first instar showed most and fourth instar the least clumping. The maximum number of first instar larvae collected by a single dip was 219, second instar 88, third instar 44, and fourth instar 17.

Figure 1 shows dipping results for first, third, and fourth instar larvae. It will be noticed that 84.20% of the first instar and 79.45% of the third instar larvae were found along the grassy margins of the plots. Second instar larvae also were found primarily along the grassy region, while fourth instar larvae were least concentrated in the marginal grassy area; only 27.75% of the latter were found in the margin.

Within marginal grassy areas (northeast and southwest borders and head and tail end of the plot) more larvae were found adjacent to the tail end or northwest border (62.38% first; 35% third; 15% fourth). At the head end (southeast) where the irrigation water entered, the least number of lar-

Figure 1. Schematic representation of pattern of dipping and actual number of larvae taken at 100 sampling stations in the plots.

First Instar				Third Instar				Fourth Instar			
219	46	191	71	5	25	24	4	3	15	2	0
9	1	34	16	7	38	4	5	7	7	0	0
7	0	20	15	6	3	3	4	4	5	3	0
6	0	1	28	3	6	0	3	1	16	0	0
2	0	5	21	4	3	0	0	1	8	0	0
2	1	0	45	1	0	0	1	1	6	4	0
1	0	1	27	2	1	1	0	0	0	5	0
1	0	1	18	20	1	0	0	1	2	1	0
0	1	2	26	20	1	0	0	0	9	1	0
0	0	1	6	10	6	1	0	0	2	7	0
1	0	3	13	8	4	0	2	0	6	2	13
0	1	1	12	6	7	1	3	0	8	1	2
0	1	1	8	2	0	1	2	0	1	0	1
0	0	0	9	11	1	2	6	0	1	0	0
0	0	2	7	10	2	3	3	0	0	0	0
1	1	5	11	0	1	1	2	0	0	0	0
0	2	7	5	4	0	1	1	0	0	0	0
0	0	8	3	0	1	0	2	0	1	0	0
0	1	1	3	4	0	1	0	0	0	1	0
0	0	0	2	6	3	0	1	4	4	2	1
0	0	1	3	2	0	0	1	1	15	2	1
0	0	0	0	0	0	0	0	1	16	2	0
0	0	1	1	0	0	0	1	0	17	3	0
0	0	0	1	2	1	0	3	2	6	0	1
0	0	0	0	0	0	0	1	1	0	0	0

Irrigation Ditch

vae were collected (0.1% first; 2.2% third, and 4.4% fourth instar).

The time of day also affected the distributions. For example, in a study of the distribution of first instar larvae that was made in the early morning (9 a.m.) 37.30% of the larvae were collected from the northeast margin, and only 26.46% from the southwest marginal area. The distribution map of the third instar larvae (Figure 1) was made from afternoon collections (2 p.m.; only 19.32% of the larvae were collected in the northeast, while 58.60% were from the southwest marginal border.

The clumped distribution of larvae is probably the result of: (1) topographical heterogeneity of the test plots (grassy areas provide better protection to larvae from the movement of air and water; moreover, the heavy concentration of larvae at the tail end of the plot is probably caused by the flow of irrigation water), (2) oviposition behavior of females (females oviposit egg masses along the grassy borders of the plots), (3) availability of food materials (microorganisms, organic and inorganic materials are probably more abundant among the dense marginal vegetation), and (4) the position of the sun; a preliminary laboratory study indicated that larvae of a given instar may react positively or negatively to light, depending on various conditions (Husbands, 1964).

Summary

The pasture mosquito larvae were found to be dispersed in a clumped pattern in the pasture; more clumpings were noticed along the grassy borders and the tail end of the test plots. There was more congregation of younger than of older larvae. The sites of clumping also appeared to be affected by the position of the sun.

References Cited

Anscombe, F.J. 1949. The statistical analysis of insect counts based on the negative binomial distribution. Biometrics 5:165-173.

Bliss, C.I., and A.R.G. Owen. 1958. Negative binomial distributions with a common K. Biometrika 45:37-58.

Hocking, B. 1953. Notes on the activities of *Aedes* larvae. Mosq. News 13:77-81.

Husbands, R.C. 1964. The reaction of mosquito larvae to light. Proc. Calif. Mosq. Control Assoc. 32:39.

Lewallen, L.L. 1963. Field tests on the persistence of mosquito larvicides in alkaline water in California. Mosq. News 23:7-9.

Pielou, E.C. 1957. The effect of quadrant size on the estimation of parameters of Neyman's and Thomas's distributions. J. Ecol. 45:31-47.

Utida, S., T. Kono, S. Watanabe, and T. Yoshida. 1952. Pattern of spacial distribution of the common cabbage butterfly, *Pieris rapae*, in a cabbage farm. In Entomol. Lab. Kyoto Univ. (ed). Researches on Population Ecology 1:49-64.

Wadley, F.M. 1950. Notes on the form of distribuiton of insect and plant populations. Ann. Entomol. Soc. Amer. 43:581-586.

Water, W.E. 1959. A quantitative measure of aggregation in insects. J. Econ. Entomol. 52:1180-1184.

Water, W.E., and W.R. Henson. 1959. Some sampling attributes of the negative binomial distribution with special reference to forest insects. Forest Sci. 5:397-412.

DAILY FLIGHT RHYTHMS OF *AEDES MELANIMON* DYAR ON DUCK CLUB LANDS OF THE WEST SIDE OF THE SAN JOAQUIN VALLEY OF CALIFORNIA

Takeshi Miura[1] and David E. Reed[2]

Until the recognition of *Aedes melanimon* Dyar by Barr (1955), Carpenter and LaCasse (1955), and Richards (1956), this species was considered to be a synonym of *Aedes dorsalis* (Meigen). Since then, Bohart (1956) and Chapman and Grodhaus (1963) have supplied additional reliable characters for the separation of these two species.

A. melanimon is one of the important pest mosquitoes in certain areas of the San Joaquin Valley. This species breeds in large numbers and disperses into residential areas (Smith 1952; Smith et al. 1956; Whitesell 1965; Reed un-

[1]University of California, Mosquito Control Research Laboratory, Fresno.

[2]Fresno Westside Mosquito Abatement District, Firebaugh.

published report). It develops primarily in the wild-flooded areas, such as the duck clubs of the west side of the San Joaquin Valley; it is also found in irrigated pastures in association with *Aedes nigromaculis* (Ludlow), though there are some differences in their geographical and seasonal distributions (Chapman 1960; Kliewer et al. 1964). In pastures producing both species, *A. melanimon* populations develop more adundantly in the spring, are outnumbered by *A. nigromaculis* during the summer months, and then become the dominant species in the fall.

Insofar as its biology and behavior are concerned, very little is known (Telford 1958; Chapman 1960; Kliewer et al. 1964, 1967). In order to provide some information on the daily flight activity of this species, a study was conducted at the Brito Gun Club of the west side of the San Joaquin Valley in the fall of 1968.

Methods and Materials

Flight activities were determined from 24-hour collections during October, 1968, using both a standard American light trap and a Malaise trap. The light trap was operated at the gun club lodge on the south side of a cabin, and the Malaise trap, without bait, was set up on dry land about 500 yards southeast of the light trap. Specimens collected at each hour were anesthetized with CO_2 and transferred to a dixie cup (8 oz.). At the laboratory, about a day after the collections were made, the mosquitoes were killed with chloroform, identified, counted, and sexed. A few specimens were picked at random from the collections for examination of age composition. Observations were also made concerning such activities as landing, biting, and swarming. Data on wind speed and direction, temperature, and relative humidity were gathered at the Fresno Westside Mosquito Abatement District Office in Firebaugh.

Table 1. Twenty-four hour collection of *Aedes melanimon* at the Brito Gun Club on the west side of the San Joaquin Valley of California.

Time of Day	Light Trap			Malaise Trap		
	Male	Female	Total	Male	Female	Total
1500-1600	0	0	0	0	0	0
1600-1700	194	88	282	0	0	0
1700-1800-	475	317	792	47	155	202
1800-1900	240	80	320	45	88	133
1900-2000	721	221	942	39	29	68
2000-2100	198	70	268	206	123	329
2100-2200	582	389	971	373	205	578
2200-2300	264	171	435	339	172	511
2300-2400	131	79	210	245	152	397
2400-0100	79	56	135	247	142	389
0100-0200	8	16	24	224	152	376
0200-0300	21	43	64	81	88	169
0300-0400	42	103	145	133	168	301
0400-0500	12	24	36	178	155	333
0500-0600	8	6	14	344	618	962
0600-0700	0	1	1	259	255	514
0700-0800	1	1	2	59	55	114
0800-0900	0	0	0	43	32	75
0900-1000	0	0	0	22	16	38
1000-1100	0	0	0	9	2	11
1100-1200	0	0	0	12	3	15
1200-1300	0	0	0	8	0	8
1300-1400	0	0	0	4	3	7
1400-1500	0	0	0	0	1	1
1500-1600	0	1	1	0	0	0
Total	2976	1666	4642	2917	2614	5531

Observations

Twenty-four hour collections from the light trap and the Malaise trap are tabulated in Table 1. Many *A. melanimon* (2,976 males and 1,666 females) were captured by the light trap. Engorged females were not collected. These collections also contained two male specimens of *A. nigromaculis*, six male and seven female *Culex tarsalis*, and one male and one female *C. erythrothorax*. In contrast, the Malaise trap collected 5,531 specimens of *A. melanimon* (2,917 males and 2,614 females) including nine engorged females, one female *A. nigromaculis* and one male *C. tarsalis*.

The mosquitoes collected by both traps were probably two to three days old; all of the male terminalia examined were completely rotated. Of the females examined, 30% were teneral and 70% post-teneral and about 33% were inseminated.

Figure 1 shows the relationship of flight activity of *A. melanimon* to the daily environmental changes, such as temperature, relative humidity, light intensity, wind, and others. Newly emerged mosquitoes rest in grasses or brush adjacent to their breeding sites during the day. About 4 p.m. (Pacific Standard Time) the western skies were lighted up with the setting sun; the local weather conditions changed rapidly (lower temperature and higher relative humidity) and became much more favorable for flight activity. Females were sighted in the air sporadically around 5 p.m.; landing and biting were also noticed. The first swarm of males was formed over the observers at 5:30 p.m. (23 foot-candles, Gossen Lunasix photo-exposure meter) and continued until 6:15 p.m. (0.11 foot-candles). These activities were repeated at dawn: at 5:20 a.m. severe bitings were observed; morning swarms were detected by the swarming sound at 5:30 a.m. (0.028 foot-candles) and terminated around 6:15 a.m.

Changing light intensity appeared to play the most important role in triggering and terminating flight activity. Rapidly diminishing light intensity initiated flight activity and it is very closely associated with higher relative humidity and lower temperature which, in turn, are the most essential conditions for flight activity. In the fall, the morning weather condition is favorable for flight; however, flight activity completely ceased as soon as light intensity increased at the end of dawn. About 63% of the catch by the two sampling traps was made between 5 p.m. and midnight, and 35% after midnight to the following dawn.

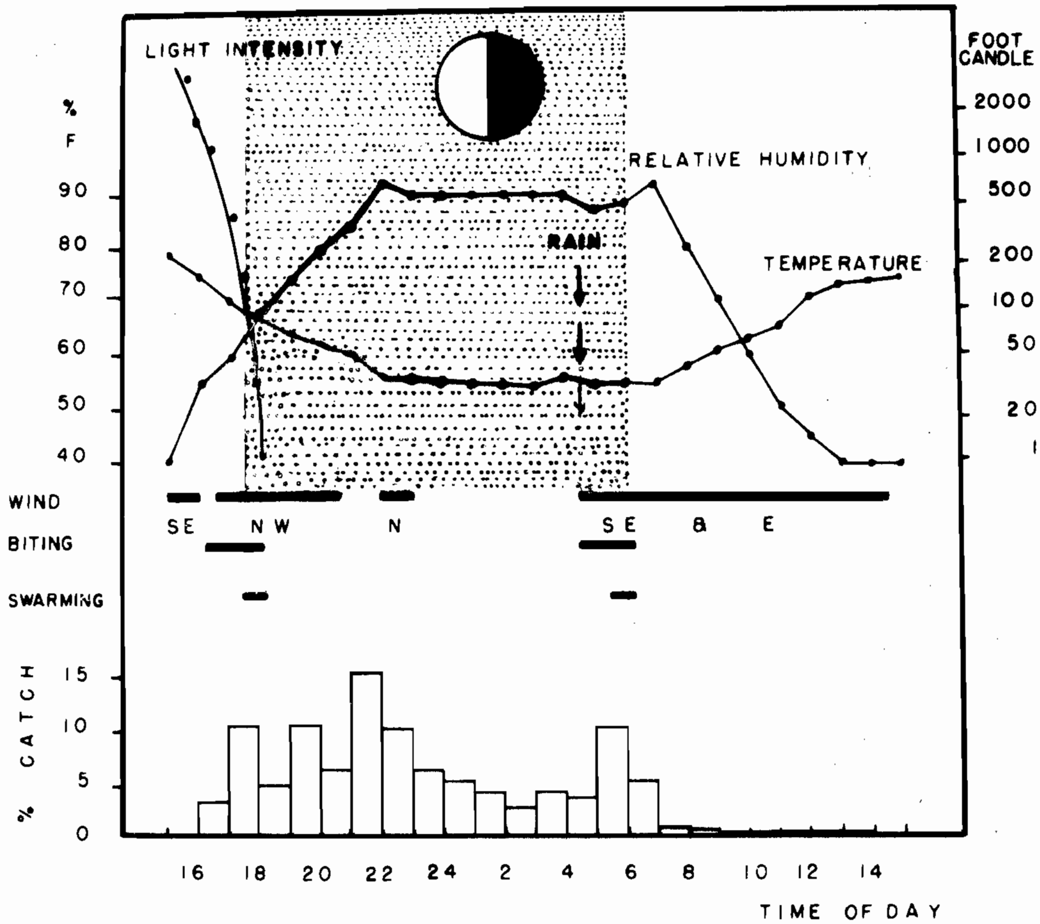


Figure 1. Relationship of daily flight activity of *Aedes melanimon* as shown by the hourly catches in traps to daily weather change at the Brito Gun Club on the west side of the San Joaquin Valley of California, 1968.

The results of the light trap collections are shown in Figure 2. The collections from the light trap probably resulted from the following activities: random flights from breeding sites to the vicinity of the light trap (non-directed flight), flights induced by the attraction of the light (directed flight), and forced flight by the trap-fan (around the light) into the killing jar.

Sixty-four percent of the total number of mosquitoes collected in the light trap (4,642) were males. To determine whether this sex-ratio was due to chance alone or some other factors were involved, the counts of the hourly catches were transferred to square root $[Y_i = (X_i + 0.5)^{1/2}]$ and analyzed ("Student's" t-Test with paired observations). The result of the test showed the differences observed were significant at the 1% level (t=3.098), which probably indicates that the position of the trap and age of the population could influence the sex ratio in the collections.

Although the results of the light trap catch show a small peak at the mid-point between midnight and dawn, 91% of the total collection was made between dusk and midnight; this could indicate that light attraction is much stronger under the evening environmental conditions than those of dawn.

The collections made by the Malaise trap (Figure 2) probably resulted from random, non-directed flight, which brought mosquitoes to the wall of the trap, and an upward movement which brought the mosquitoes into the collecting chamber. More mosquitoes (60%) were collected from midnight to dawn than from dusk to midnight. Since the Malaise trap was operated without bait, the mosquitoes collected by the trap were likely in random flight. In both trap collections, the peak at dawn contained a proportionally higher number of females (Table 1); it is interesting to note that the observers also noticed severe biting activity at dawn.

More males were obtained by the Malaise trap than females; however, the discrepancy is not significant at the 1% level (t = 1.145).

The result of the 24-hour collections obtained from the traps shows that flight activity, at this time of year, continued throughout the night, thus providing more chance to the mosquitoes to disperse (Figure 1). This might partially explain the fall population displacements of *A. melanimon* from untreated areas into treated areas, as has been suspected by mosquito control agencies.

Summary

Daily flight rhythms of *Aedes melanimon* were determined by hourly catches in light and Malaise traps. Flight activity started gradually at dusk and continued to dawn. Catches showed bimodal peaks; the first peak was at the period between dusk and midnight and the other between midnight and dawn. More mosquitoes were caught between dusk and midnight by the light trap; however, the Malaise trap produced the largest catch between midnight and dawn. The result of the trap collections shows that flight activity is nocturnal in the fall.

Daily flight activity of *A. melanimon* is not well understood; these results indicate the need for further study of flight activity throughout the mosquito season.

Acknowledgments

We wish to express our appreciation to Drs. D.P. Furman and C.H. Schaefer for comments on the manuscript, and to Dr. J.B. Hoy, USDA, ERD, Fresno, for the loan of the Malaise trap.

References Cited

Barr, A.R. 1955. The resurrection of *Aedes melanimon* Dyar. Mosq. News 15:170-172.

Bohart, R.M. 1956. Identification and distribution of *Aedes melanimon* and *Aedes dorsalis* in California. Proc. Calif. Mosq. Control Assoc. 24:81-83.

Carpenter, S.J., and W.J. LaCasse. 1955. Mosquitoes of North America. University of California Press, Berkeley and Los Angeles. Page 366.

Chapman, H.C. 1960. Observations on *Aedes melanimon* and *A. dorsalis* in Nevada. Ann. Entomol. Soc. Amer. 53:706-708.

Chapman, H.C., and G. Grodhaus. 1963. The separation of adult females of *Aedes dorsalis* (Meigen) and *A. melanimon* Dyar in California. Calif. Vector Views 10:53-56.

Kliewer, J.W., T. Miura, and K.E. White. 1964. Temperature and salinity relationships of *Aedes nigromaculis* and *A. melanimon*. Proc. Calif. Mosq. Control Assoc. 32:42-45.

Kliewer, J.W., B. Rosay, T. Miura, C.M. Myers, and M.M. Boreham. 1967. Swarming and mating of some California mosquitoes. J. Med. Entomol. 4:490-494.

Reed, D.E. 1968. Flight observations of *Aedes melanimon* and *Aedes nigromaculis* during the fall of 1967. Spec. Rep. Fresno Westside Mosquito Abatement District, Firebaugh, Calif.

Richards, C.S. 1956. *Aedes melanimon* Dyar and related species. Can. Entomol. 88:261-269.

Smith, G.F. 1952. *Aedes* flight studies – 1951. Proc. Calif. Mosq. Control Assoc. 20:26-30.

Smith, G.F., A.F. Geib, and L.W. Issak. 1956. Investigations of a recurrent flight pattern of flood water *Aedes* mosquitoes in Kern County, Calif. Mosquito News 16:251-256.

Telford, A.D. 1958. The pasture *Aedes* of central and northern California. Seasonal history. Ann. Entomol. Soc. Amer. 51: 360-365.

Whitesell, K.W. 1965. Large scale granular pre-treatment of a duck club area in the Colusa Mosquito Abatement District. Proc. Calif. Mosq. Control Assoc. 33:56-57.

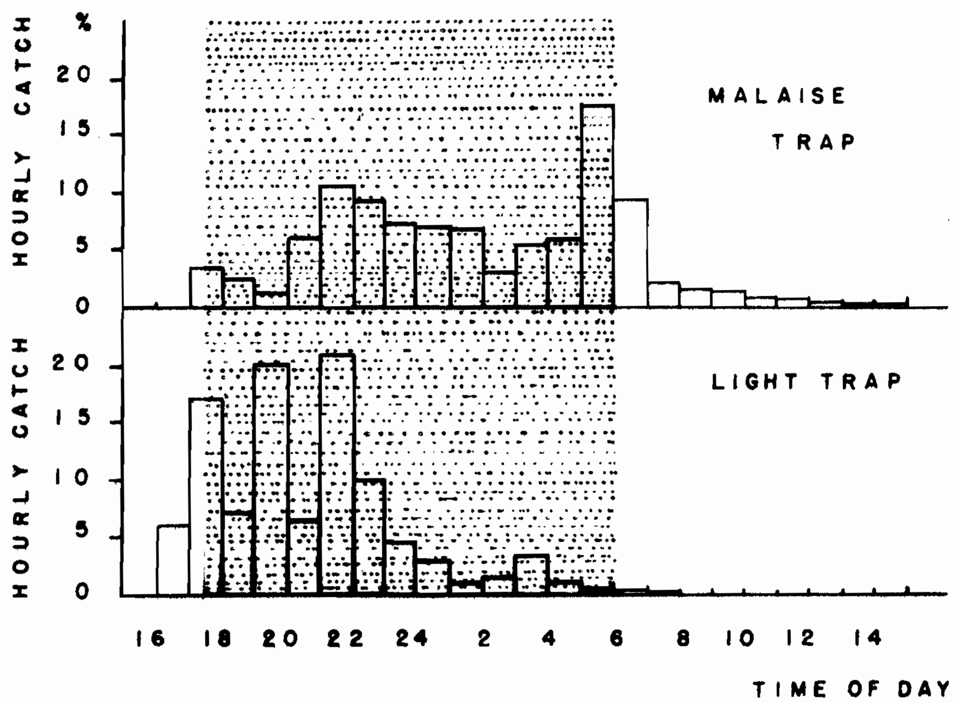


Figure 2. Hourly collections of *Aedes melanimon* in traps at the Brito Gun Club on the west side of the San Joaquin Valley of California, 1968.

INTEGRATION OF LARVAL SURVEILLANCE TECHNIQUES IN THE OPERATIONAL PROGRAM OF THE FRESNO WESTSIDE MOSQUITO ABATEMENT DISTRICT

David E. Reed[1] and Richard C. Husbands[2]

Organized mosquito control operations started in the northwest portion of Fresno County in April, 1959 following the formation of the Fresno Westside Mosquito Abatement District. During the first three years of the District's operation the greatest efforts were expended in developing a sound organization and program. Mosquito population measurement during these initial years was based primarily on adult mosquito sampling, during the active mosquito season, using a mechanical trap as described by Mulhern (1953). Aspirator collections of adult mosquitoes were also made during the winter months.

Larval sampling was limited to random collections made by technical staff. Collections were placed in pint ice cream cartons and larval identifications were made in the laboratory. Documentation was limited to summaries sent to the State Department of Public Health, Bureau of Vector Control.

Beginning in 1962, larval surveillance became a routine activity for most District personnel. One-half to one day was scheduled each week for larval surveillance, from mid-February through August. This routine was continued until 1967. From 1962 to 1967 collections were made in the field by selecting larvae from a dipper with a medicine dropper and depositing larvae into a 2-dram vial containing 50% isopropyl alcohol. Preserved mosquitoes were identified in the laboratory and a record kept of larval density and stages of development.

The feeling that considerable valuable information was slipping by unnoticed, and a concern for increasing resistance of mosquitoes to insecticides, prompted an expanding program of daily larval surveillance by all field operators, starting in 1967. Agency-wide and continuous larval surveillance programs have been tested and reported from Utah (Graham and Bradley, 1962, 1965; Collett, et al., 1964). The techniques used in these programs have been studied and adapted to the particular problems and needs of the Fresno Westside MAD.

The need for a planned, systematic, district-wide larval surveillance program which would encourage maximum effort by the entire staff throughout the mosquito season was the basic reason for extending larval sampling efforts in the District.

To justify this program, which would require additional effort including an expanded record keeping system, the following specific advantages were considered:

1. Routine larval surveillance provides a more complete and accurate record of sources, thereby providing documentation of mosquito production as a basis for treatment.
2. Routine larval surveillance allows for continuous evaluation of insecticide application, timing, and control results.
3. Clear understanding of mosquito species distribution, density, and seasonal occurrence is only possible through routine larval surveillance which can be applied to integrated control.
4. Routine larval surveillance greatly enhances the intelligence system provided through adult mosquito surveillance (use of light traps and resting stations).
5. A ready-made system for insecticide resistance detection is provided through such a surveillance program.
6. This approach to larval surveillance should be a valuable aid in coordinating chemical control with farming operations that depend upon the use of noncompatible chemicals (e.g., propanil in rice).
7. It provides epidemiological information necessary for the interpretation of actual or potential mosquito-borne disease occurrence.
8. It will provide the information to support research on problems revealed by the expanded program.

Methods

The 1967 and 1968 larval surveillance programs started as soon as control operations began in February and continued to the end of the control season late in October. Unlike the 1965 and 1966 programs which consisted of sampling only one day a week, all control operators sampled daily with each inspection. All inspections were recorded on a daily report. Weather and related field conditions were recorded in this report. The report also included the time of day inspection was made, location, property owner, estimated larval density, and time taken for inspection or spraying. Larval density estimates were calculated by dividing the total number of larvae observed by the number of dips taken.

Larvae from each dip were drained into a small cylindrical screen in a hand concentrator (Husbands, 1969). Roughly half of the inspection time was devoted to this sampling activity. The concentrator screen and its contents were placed in 6-dram vials filled with 50% isopropyl alcohol. Vials were then corked and labeled to correspond with the daily report. All samples were deposited daily, along with the daily reports, in the laboratory for identification. Species, number, and instars represented were identified and recorded. For special projects, the number of specimens representing each instar was also recorded.

Many hours of manual effort were spent in the retrieval of data compiled for this evaluation. Information could be summarized in many other ways depending upon the objective or purpose of the tabulation. It is apparent that this information could be used for daily program guides if sophisticated electronic data processing equipment was incorporated as a part of this technique.

[1]Manager-Entomologist, Fresno Westside Mosquito Abatement District, Firebaugh.

[2]Senior Vector Control Specialist, State Department of Public Health, Fresno.

Results

Since the Fresno Westside MAD has expanded its larval surveillance program, the question may be asked, "What effect has the additional sampling had upon the validity of our surveillance data?" In an effort to answer this question, the number of larval sources containing each species was determined. The total number of inspections made during the sampling period was used as a common denominator. The results are expressed in percent and are summarized in Table 1.

Although two years' data are not sufficient to do more than establish a baseline, the similarity in the percent of sources containing mosquitoes in all four years is striking. This is not necessarily surprising since procedures followed during 1965 and 1966 were similar to those used in 1967 and 1968, the essential difference being the increased number of inspections during the past two years. The significance of the relative numbers of the species taken is, of course, subject to question owing to the small number of samples taken in 1965 and 1966. The increased rate in appearance of *Culex tarsalis* in 1967, the first year of routine daily sampling, may be significant, since that year was considered to be a relatively low one for this species in this area. Improved and intensified sampling in rice areas during June, July, and August of 1967 and 1968 may account in part for the higher counts. The general use of propanil herbicide in rice in 1967 and 1968 may also be a significant variable having a bearing on this case. At least another two years of observations will be needed to establish valid lines of comparison.

An indication of the change that rice cultural practices have made in mosquito production and species composition in the rice field complex can be drawn from the figures in Table 2. The appearance of *Aedes melanimon* in drains, seepage, and the rice field itself at mid-season is the most significant development attributable to the change in cultural practice. Complete drainage of rice fields prior to the application of propanil herbicide provided ample oviposition sites for *A. melanimon.*

In our effort to obtain more precise information on species distribution in irrigated pastures in different areas of the district, a different approach was taken. Since we were not recording all negative inspections in pastures, the use of total inspections was felt to be unreliable. A comparison of species composition and frequency of occurrence in sources containing larvae only was used instead. During the March-October period, for example (Table 3), *Aedes nigromaculis* was the species found most frequently in irrigated pastures. *A. nigromaculis*, however, was found in pastures only a little over half the time (54.3%) in the entire district and only slightly more frequently in the southern division than in the northern division of the district. *A. melanimon*, on the other hand, was found more frequently in the north than in the south, but its frequency of occurrence was comparable to *A. nigromaculis* in the north. Of special interest was the frequency of *C. tarsalis* appearance in pastures, particularly in the southern area.

The significance of results obtained in irrigated pastures should probably be interpreted in the light of certain general conditions. While the number of irrigated pastures in the two divisions is comparable, only 30% of the total acreage in the district is located in the northern division. Pastures in this division are therefore smaller. Also, soils in the northern division are of the deep cracking Merced and Tem-

Table 1. Relative incidence of important mosquito species found in all sources in the Fresno Westside Mosquito District during the years 1965-1968.

Species	Percent of positive sources[1,2] 1965	1966	1967	1968
C. tarsalis	13.8	13.6	15.8	17.3
A. nigromaculis	3.8	3.7	4.6	4.3
A. melanimon	4.7	6.4	3.2	4.7
A. freeborni	0.4	0.4	0.6	0.9
[1]Total positive sources (%)	24.4	25.9	25.6	25.6
[2]Total sources inspected	3,693	3,941	16,955	21,845

Table 2. Number of sources containing mosquito larvae and frequency of appearance of each mosquito species as related to inspections in rice environment at the Fresno Westside Mosquito Abatement District.

	Sources Inspected			Occurrence of Species – Percent			
	Year	Number	Percent* Positive	*C. tarsalis*	*A. freeborni*	*A. melanimon*	Other species
Rice	1967	1,598	39.9	40.3	1.4	0	0
	1968	2,016	50.7	48.3	3.4	0.7	1.4
Rice Seepage	1967	477	35.4	35.5	0.6	0.8	0.8
	1968	248	60.9	53.8	2.8	6.1	0.4
Rice Drains	1967	121	42.1	42.2	1.7	0	3.3
	1968	98	70.4	64.3	3.1	7.1	4.1

*Each species can be found alone or in mixtures in a single positive sample, therefore, the percent occurrence of species does not equal the percent of sources positive.

Table 3. Mosquito species distribution and frequency in irrigated pastures in the northern and southern divisions of the Fresno Westside Mosquito Abatement District in 1968.

Division	Northern		Southern		Total	
Number of Pastures	621		571		Pastures 1,192	
Species	p/w[1]	% of Total	p/w[1]	% of Total	Total	(%)
C. tarsalis	187	30.2	237	41.5	424	35.5
A. nigromaculis	312	50.3	336	58.8	648	54.3
A. melanimon	285	45.9	155	27.2	440	37.9
C. inornata	15	2.4	18	3.2	33	2.8
Other species	14	2.3	11	1.9	25	2.1

[1] p/w – Pastures With

ple clay group, whereas in the southern division pastures are located in poorly drained soils of the Fresno and Traver hardpan and claypan groups.

Mosquito species composition and frequency of occurrence in irrigated pastures are summarized in Table 4. This tabulation shows the number of times each species was found alone and in combination with other species. As expected, *A. nigromaculis* was the most frequently found species, in combination with other species or alone. Of particular significance, and of great importance from the standpoint of source reduction operation, is the number of times *C. tarsalis* was the only species found in pastures.

Discussion and Conclusion

Interpretation of mosquito densities in district-wide evaluations has limitations in the present larval surveillance program. Larval densities have more meaning when related to type and size of source and time of sampling. Since larval densities were recorded throughout the season, projection of relative abundance and distribution in various types of sources is possible. For example, greater densities of all mosquito species were recorded in irrigated pastures in the northern areas than were in the southern areas of the district (Table 5). As previously mentioned, pastures in the northern division are much smaller, thus better sampling was possible. This probably accounts to a large extent for the apparent population differences.

The reliability of mosquito density figures reported by District operators was tested in rice fields in 1968. A dipping station was located in 87 rice fields and a stake was driven in the center of a check about 30 feet from the edge of the field, thereby marking the location of the station. Ten dips were taken in the general area of the stake. In addition, for control purposes, mosquito densities beyond the station were estimated in the manner previously described for routine sampling. Results during the season showed average larval densities at all stations containing larvae to be .45 per dip, whereas larval density in all district rice fields averaged only .25 per dip – about half that of stations. Third and fourth instar larvae and pupae were collected at stations at the rate of 0.25 per dip. Thus, it is likely that operators tend to "estimate" larval density during routine operations by counting the late instars. The reliability of estimated larval densities, as presently determined, is therefore subject to question.

This study was concerned primarily with analysis of species composition, density, and distribution on a geographical basis, drawn from an annual summary. Species composition, density, and distribution data determined on a chronological basis in "time" are of great operational value. This district has used the kinds of surveillance information discussed here as guides in timing mosquito control operations, to evaluate the ability of operators to make accurate mosquito species identification in the field, to evaluate the judgment of field personnel regarding their recommendations for control procedure to be undertaken, to delineate species distribution on a weekly basis and to project possible future trends, and to coordinate mosquito control operations with the weed control program of rice growers.

Information thus far obtained from the expanded surveillance program tends to confirm subjective observations made by experienced mosquito control workers in the district over a period of years. Data acquired have also been used to detect deficiencies in the inspection procedures of field personnel and will be used in the future to build greater precision into the control program of the district.

Considerable effort has been extended by all district personnel to extract, condense, and interpret only a fraction of

Table 4. Mosquito species combinations in 1,192 irrigated pastures containing larvae in 1968.

Species	Number of Pastures Containing 1 or 2 Species: *Culex tarsalis*	*Aedes nigromaculis*	*Aedes melanimon*	*Culiseta inornata*	Other	3 or more spp.	Total	Percent of 1,192 Pastures
Culex tarsalis	235	68	59	14	8	40	424	35.5
Aedes nigromaculis	68	405	140	1	2	32	648	54.3
Aedes melanimon	59	140	203	2	1	35	440	37.9
Culiseta inornata	14	1	2	4	1	11	33	2.8
Other species	8	2	1	1	9	4	25	2.1

Table 5. Estimated larval concentrations of mosquito species in irrigated pastures in the northern and southern divisions of the Fresno Westside Mosquito Abatement District in 1968.

Division	Northern	Southern	
Species	Average Number Larvae Per Dip		District Average
Culex tarsalis	1.40	1.19	1.28
Aedes nigromaculis	2.31	1.00	1.64
Aedes melanimon	2.69	0.47	1.80
Culiseta inornata	0.83	0.30	0.56
Other species	0.91	2.43	1.57

all the raw data collected during the year. Eventually more sophisticated data processing equipment and procedures should greatly simplify this vital element of our control program.

References Cited

Collett, Glen C., Jay E. Grahan, and Iver E. Bradley. 1964. Relationship of mosquito light trap collection data to larval survey data in Salt Lake County. Mosq. News 24(2):160-162.

Graham, Jay E., and Iver E. Bradley. 1962. The effects of species on density of mosquito larval populations in Salt Lake County, Utah. Mosquito News 22(3):239-247.

1965. *Culiseta inornata* (Williston) and temperature in Utah. Mosquito News 25(2):107-111.

Husbands, Richard C. 1969. An improved technique of collecting mosquito larvae for control operations. Calif. Vector Views 16(7):67-72.

Mulhern, Thomas D. 1953. The use of mechanical traps in measuring mosquito annoyance. Proc. Calif. Mosq. Control Assoc. 21:64-66.

A COMPARISON OF LARVAL MOSQUITO SPECIES OCCURRENCE AND LIGHT TRAP DATA

Richard C. Husbands[1] and David E. Reed[2]

Mosquito control agencies have been forced by many circumstances to depend to a great degree upon subjective methods of evaluating mosquito populations and related operational problems. Objective evaluation has been very difficult to obtain although many efforts have been made by control agencies to overcome the limitation of the time and accuracy required in the field and laboratory to obtain useful data. While light trap mosquito surveillance has been developed as a useful guide, larval sampling indices, which are more difficult to obtain, have had limited application. Loomis (1959) discussed the use of larval indices in California as an aid to encephalitis surveillance and commented upon the need for a more precise method of measuring larval density.

The data obtained by sampling both adults and larvae range from simple species distribution identification to more elaborate density determinations. Light trap samples, collecting station counts, biting counts, landing rates, bait trap collections and immature mosquito surveys are some of the common procedures used for source evaluation and density determination. Frequently the objectives of these surveillance activities are to measure the success or failure of chemical treatment, to provide a base line for control cost analysis, and eventually to justify a changeover to source reduction. Other possible objectives include obtaining information required in planning operations or obtaining preliminary information on insecticide resistance.

In California, light trap data have been used extensively as aids in forecasting and evaluating arbovirus transmission (Reeves 1968). In addition, control agencies use light trap data to locate control failures, to detect adult migration, and to measure seasonal distribution, frequency, and occurrence of species. Largely awaiting elucidation is the influence upon the data of weather, as well as trap location (which in communities can, in effect, shift without moving as the community builds up around it). This and the importance of other factors that influence sampling have been discussed by Barr (1960) and Haufe (1960). Loomis (1953) attempted to use resting station data and observed that the many variables made the analysis very difficult.

Larval surveys in California are less extensive and less standardized than adult measurements. An early season statewide larval surveillance program has been developed, primarily to alert agencies regarding the occurrence of immature *Culex tarsalis* in a wide variety of man-made and natural sources. Control agencies also use larval surveys to determine or confirm the occurrence of species in different habitats, and the need for control as well as for measuring the degree of control obtained. The data are generally used or expressed in very simple terms.

Administrators of control programs sometimes feel that the time and effort devoted to this kind of documentation cannot be justified because of the time required for compilation and evaluation. Also, there is a feeling that the data obtained are of questionable statistical validity. Although these objections are valid there are several new methods available to help overcome these handicaps. They consist of improved techniques for collecting field samples, simplification of data recording, and automation of records (data processing) which can be programmed to perform the tedious task of compiling data, making analysis, and performing statistical tests.

This report will illustrate the value of using several types of data to evaluate the complex variations that occur in mosquito populations and related control operations. In the process the justification will become more evident.

The pioneering work in Utah (Graham and Bradley 1961 and 1962 and Collett et al. 1964) has helped lay the ground-

[1]Senior Vector Control Specialist, State Department of Public Health, Fresno, California.

[2]Manager-Entomologist, Fresno Westside Mosquito Abatement District, Firebaugh, California.

work for a more effective method of evaluating mosquito populations as a part of an operational program. Data processing is a vital part of their program.

In an attempt to develop a more meaningful surveillance program the Fresno Westside Mosquito Abatement District has adopted an experimental operation designed to improve the collection and analysis of field data. The Bureau of Vector Control has been providing technical assistance in this program.

Method

Light trap samples are obtained from eight light traps operated each night. Four of the traps are located in small rural communities (population 3000 or less). Four of the traps are located in agricultural areas.

Larval surveys have been a standard part of the district's program for several years. The operators have received considerable training and experience in this activity. During 1965 and 1966, larval surveys were limited to one day a week and continued at least through August. In 1967, the program was changed to a full time surveillance procedure. Each day the operators collected larvae and recorded environmental data from each field visited during routine control procedures. Sampling procedures were standardized to the extent possible. Collections were identified in the laboratory by a trained technician.

Results

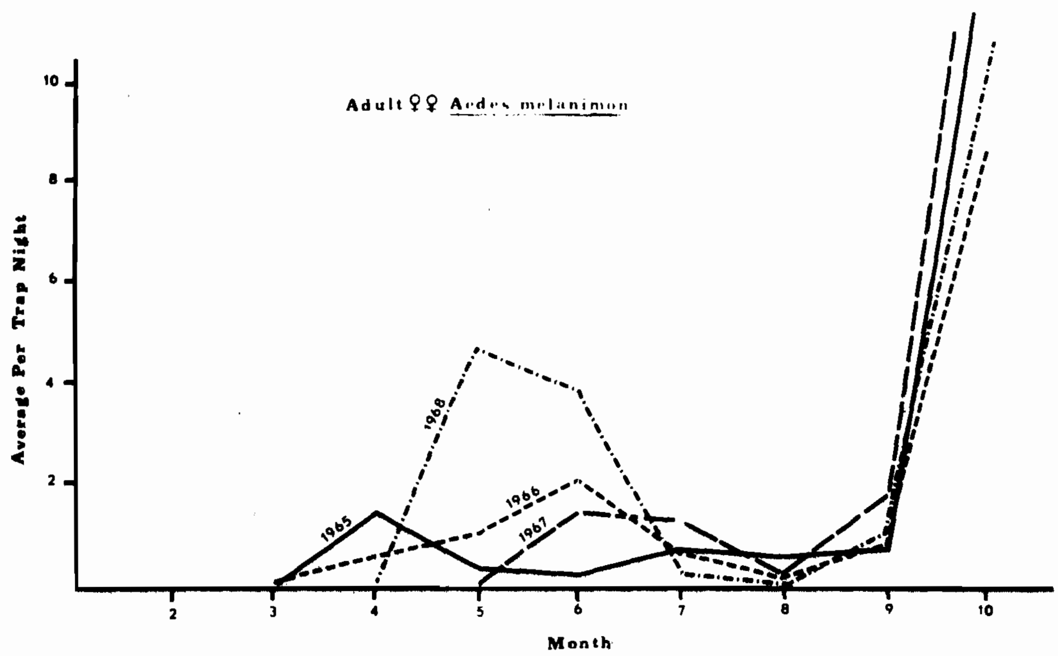
The results obtained have many interesting ramifications; however, for the purpose of this report the analysis will be limited primarily to a comparison between the results of larval sampling and light trap data.

The analysis of the data obtained by these two methods has been limited to *C. tarsalis*, *Aedes melanimon*, and *Aedes nigromaculis* over four consecutive years, 1965 through 1968. In most cases these species are associated with problems throughout the area and normally can be found either in the larval or adult stage from February to November. The data obtained have been affected to a great extent by the district's control program.

Table 1 and Figure 1 show the seasonal distribution of *A. melanimon* based on light trap and larval records. While there is no apparent seasonal correlation between these two sets of data, both show the expected bimodal population curve. Significant differences can be seen in the early season larval data. Unlike trap data, larval occurrence indicates that *A. melanimon* is found in greater numbers in the spring than in mid-summer and fall. On the other hand, the light trap data show adults present that may have emerged from field sources and invaded adjacent areas. Light trap data also show an unusual increase in the *A. melanimon* population in October while the larval data do not reflect this change. *A. melanimon* may be able to disperse over a considerable

Table 1. Comparison between Aedes melanimon light trap collection data and larval source occurrence data.

	Number of female A. melanimon collected per trap night-8 traps				Percent of sources inspected containing A. melanimon larvae			
	1965	1966	1967	1968	1965	1966	1967	1968
Feb.	-		0.00	-	4.5	0	1.78	16.85
Mar	-	.004	0	0.02	10.2	8.7	8.66	6.45
Apr.	1.37	0.30	0	0.05	2.8	6.1	3.87	7.02
May	0.36	0.84	.05	4.64	5.1	7.6	5.24	5.44
June	0.25	2.00	1.33	3.82	3.6	6.9	3.87	6.60
July	0.54	0.44	1.13	0.33	1.6	3.3	1.62	4.20
Aug.	0.41	0.12	0.39	0.13	3.1	1.5	1.94	2.80
Sept.	0.45	0.55	1.79	0.76	2.7	-	1.00	2.30
Oct.	17.91	8.65	41.39	13.27	4.4	-	1.79	2.58



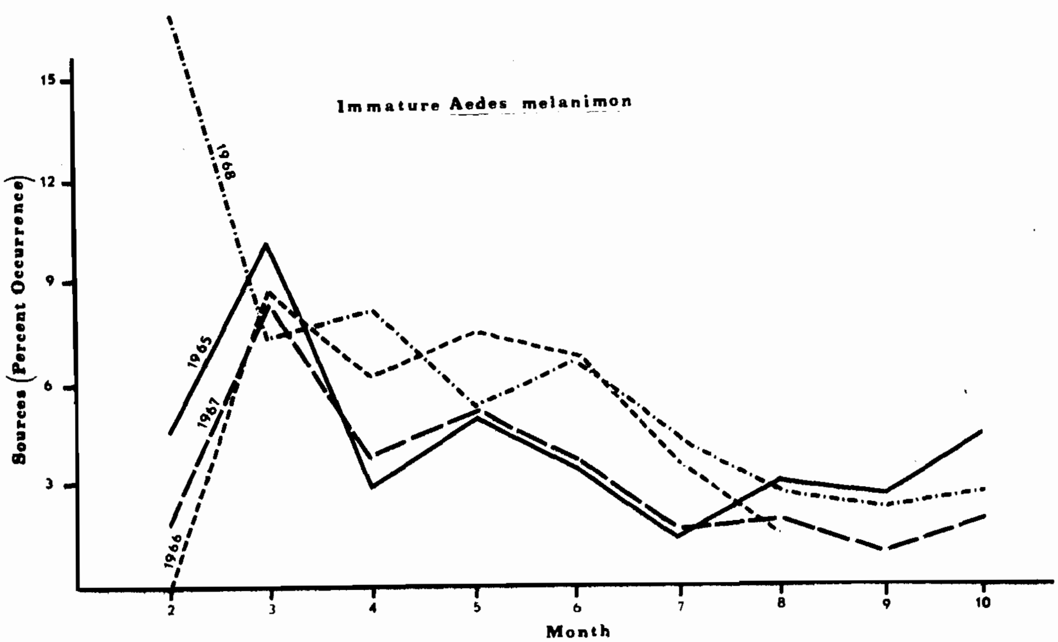


Figure 1. A four-year comparison between *Aedes melanimon* larval occurrence in all sources inspected and the number of females collected per trap night in eight traps located within the Fresno Westside Mosquito Abatement District.

Figure 2. A four-year comparison between *Aedes nigromaculis* larval occurrence in all sources inspected, average density in larvae per dip for 1968, and the number of females collected per trap night in eight traps located in the Fresno Westside Mosquito Abatement District.

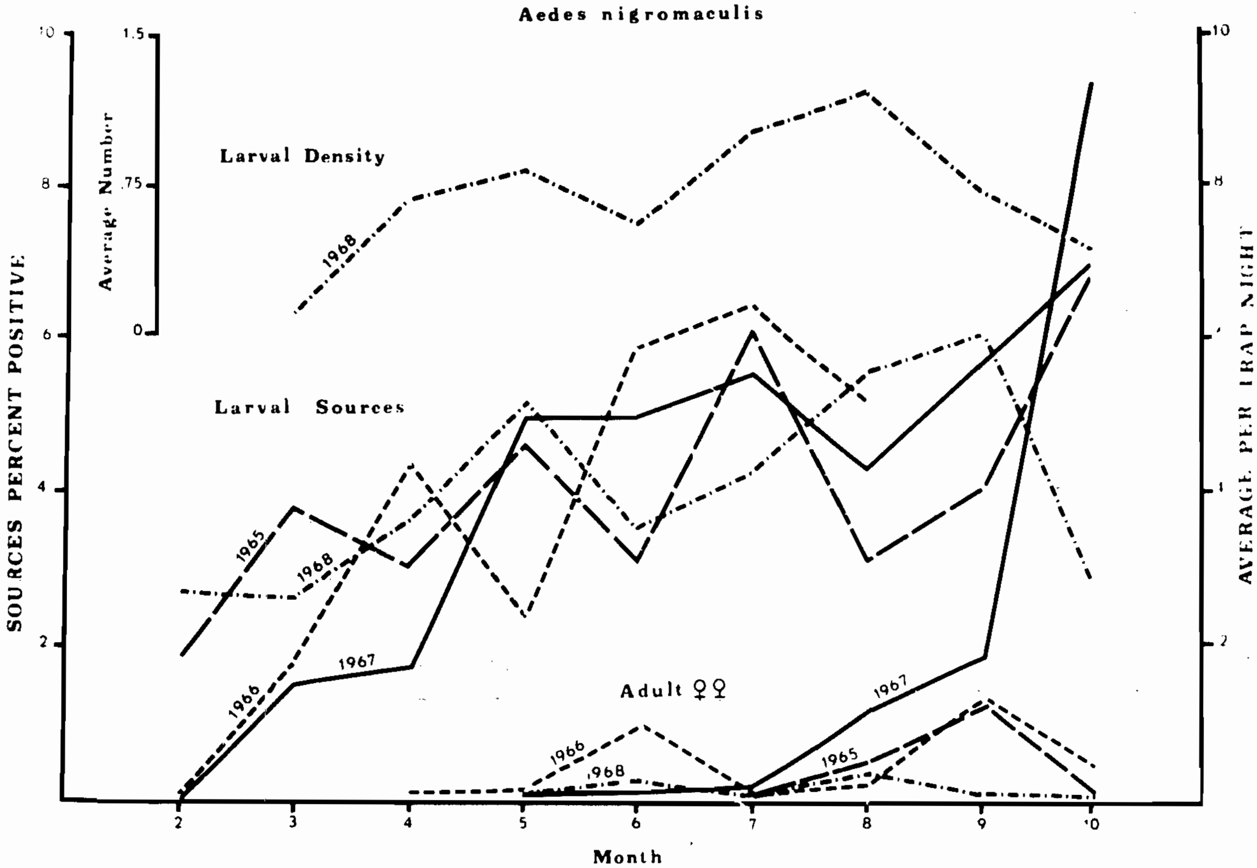


Table 2. Comparison between *Aedes nigromaculis* light trap collection data and larval source occurrence data.

	Number of female A. nigromaculis collected per trap night-8 traps				Percent of sources inspected containing A. nigromaculis larvae			
	1965	1966	1967	1968	1965	1966	1967	1968
Feb.	-	-	-	-	1.9	0	0	2.6
Mar.	0	0	0	0	3.8	1.7	1.54	2.5
Apr.	0.01	0.01	0	0	3.0	4.4	1.7	3.7
May	0.03	0.06	0.03	0.15	4.6	2.3	4.9	5.15
June	0.02	0.85	0.16	0.24	3.1	5.9	4.9	3.6
July	0.12	0.06	0.36	0.07	6.0	6.4	5.5	4.2
Aug.	0.48	0.21	1.01	0.36	3.1	5.1	4.3	5.5
Sept.	1.03	1.14	1.98	0.19	4.0	-	5.8	6.0
Oct.	0.21	0.40	9.49	0.09	6.7	-	6.9	2.9

distance from emergency sites and it appears that the only explanation for the extreme increase in the numbers trapped during October is the movement of adults into the traps from sites not generally sampled for larvae.

The data obtained from larval sources in February, 1968, when compared to previous years, are difficult to explain. More years of measurement will be required to determine if this is biased by external factors or by the improved sampling procedure. However, the same trends were also reflected in the *C. tarsalis* data (Figure 3) and may have resulted from differences in rainfall and irrigation patterns for 1968 and other years studied. The 1968 light trap data also follow the trend of the unusual February, 1968, larval data by showing an extraordinary increase in adults during May and June. The need to apply control early in 1968 became more apparent when both types of data are examined. The point to be made here is that there are both biologically and operationally significant data to be obtained by comparing differences as well as similarities in both light trap and larval data. Eventually these data can be used to help attack the problems of control intelligently.

Figure 2 and Table 2 show the same type of a comparison for *A. nigromaculis*. Once again there does not appear to be a seasonal correlation between frequency of occurrence of larvae in sources and numbers of adult mosquitoes recovered in traps. In addition, data on the estimated larval densities for 1968 in irrigated pastures have been given in Figure 2. Note that the trend in sources positive for 1968 shows a strong correlation with larval density. The August peak in the *A. nigromaculis* population for 1968, as shown by density measurements, corresponds with data obtained on irrigated pastures during intensive ecological studies from 1951 through 1955 (Thurman et al. 1951; Husbands and Rosay 1952, 1953, 1954, 1955). Unlike *A. melanimon*, *A. nigromaculis* larval occurrence data show a gradual increase in the percent of sources positive from February through July. Except for 1968, when this trend continued through September, the number of positive sources dropped during August although the density increased in those sources still positive. A close examination of the types of sources involved in the change in percentage in August possibly could reveal the cause for this interesting interrelationship. Insecticide resistance also may be suspected as one of the causitive factors effecting the trend in the increased density and rate of infestation.

It is self-evident that the *A. nigromaculis* light trap data have only a limited value. The traps sample adults in such low numbers that it appears that the traps are not placed in locations adjacent to *A. nigromaculis* production. Normally this species remains near the site of emergence and urban trap sites do not adequately sample these normal field populations. However, the data for 1967 show a major change in the number of females trapped during October and may reflect an unusual production within pastures or the fall dispersal of *A. nigromaculis* from these sites.

As far as operations are concerned, the larval sampling program is much more useful as a means of determining when to start insecticide treatment as a preventive measure and, also, the significance of these sources as future problems in terms of cost, manpower, and the justification for source reduction.

The data obtained on the third species, *C. tarsalis*, are equally interesting and are shown in Figure 3 and Tables 3 and 4. There is a highly significant correlation (at the 1% level) between seasonal light trap data and the percent of sources infested. The light trap data fail, once again, to show the early season build-up of larval sources since there seems to be a four-month lag (February through May) before adult counts reflect potential production. Note the agreement in the low trend of both light trap data and frequency with which sources are found containing *C. tarsalis* during the year 1967. This was a wet year (actually February and March 1967 were below normal rainfall) during which everyone worried about *C. tarsalis* production. On the other hand, the data for 1968 (Figure 3) are unusual. The positive sources show an unusually high rate of infestation in February (as did *A. melanimon*) and although it was a dry year in the westside area, the rainfall in the critical February and March period was 5 times higher in 1968 than in 1967. Irrigation also started earlier (mid-February) in 1968 because it was warmer during these months than in 1967. Table 4 shows the occurrence of *C. tarsalis* instars in all sources sampled during the critical months of February and March, 1967 and 1968. It can be seen that the 1968 sources contained larvae with a much more advanced stage of development (another example of the value of good records). During 1967, light trap data showed an unusual increase in the number of adults collected during July – which apparently were produced by propanil treated rice fields. The use of propanil, an herbicide, prevented the use of phosphate insecticides on rice during this period. However, this is not reflected in the larval data because the propanil treated rice fields were not sampled routinely during the period when propanil was applied. This failure to sample larvae was overcome in 1968 partially as a result of this experience, also the propanil treatment was better coordinated with larval control, which also held adults to a minimum in 1968.

Vector species populations that overwinter in the adult stage generally move out of their resting phase early in the spring in this area and begin to oviposit in suitable aquatic habitats. The data in Table 3 and Figure 3 show that this is initiated in February or possibly in some cases (1968) as early as January. Larval sampling procedures show that this rate of infestation continues to rise and reaches a peak in July. Rice field habitats which occur in this area (20,000 acres) affect this rate. Adult populations as measured by light traps (Figure 3) do not follow this trend in most cases, and this may be due to the pressure of insecticide treatment. The 1967 adult data for July appear to support this theory. The July propanil treatment period released the rice fields from the pressure of mosquito control and apparently in-

Table 4. Number of sources containing mixtures of stages of immature *Culex tarsalis* during February and March 1967 and 1968 in the Fresno Westside Mosquito Abatement District.

Year	Mo.	Inclusive Dates Sampled		Instar 1	Instar 2	Instar 3	Instar 4	Instar P
				Number of Sources				
1967	Feb	14	17	0	0	0	0	0
	Feb	20	24	0	1	0	0	0
	Feb - Mar	27	3	0	2	1	0	0
	Mar	6	10	0	11	8	0	0
	Mar	13	17*	0	6	6	2	0
	Mar	20	24	0	7	7	9	1
	Mar	27	31	1	3	5	1	0
1968	Feb - Mar	27	1	23	44	24	10	0
	Mar	4	8*	40	59	64	48	11
	Mar	11	15	28	36	40	34	12
	Mar	18	22	12	45	51	47	18
	Mar	25	29	31	43	35	38	16

*First male C. tarsalis taken in light traps.

creased the *C. tarsalis* adult population. The highest counts were obtained in July from a trap adjacent to the rice area.

The habits of adult *C. tarsalis* during different periods of the year may influence the sampling data. If their movements are confined to the daylight hours, owing to cool weather at night, or if behavioral differences are induced by physiological changes in the female during this early part of the season, the light trap sample which is taken at night may miss the adult population almost entirely during March and possibly on through May. Resting station data may be equally remiss in this respect (Loomis 1953). However, CO_2 or bait traps may be able to detect this population. Eventually oviposition traps may be developed to provide the needed information. The rate at which sources are reinfested, as shown in Figure 3, provides an indirect clue to support this theory and these data should be examined closely each year by adequate sampling procedures to judge the appearance of abnormal trends as seen in 1968. The methods described here and used by the Fresno Westside Mosquito Abatement District are apparently sufficiently sensitive to perform this operation.

Conclusion

1. Light trap sampling data:

a. Data obtained from light traps vary in magnitude (Figures 1, 2, 3) depending upon both the behavior of species and the influence of external factors. The effect of weather factors, such as temperature and rainfall, may have

Table 3. Comparison between *Culex tarsalis* light trap collection data and larval occurrence data.

	Number of female C. tarsalis collected per trap night-8 traps				Percent of sources inspected containing C. tarsalis larvae			
	1965	1966	1967	1968	1965	1966	1967	1968
Feb.	-	-	-	-	0.6	1.4	0.44	25.3
Mar.	0.22	0.24	0.12	1.26	7.9	4.2	4.81	19.6
Apr.	0.49	0.82	0.04	1.42	12.6	13.8	4.69	14.3
May	0.51	1.85	0.16	1.15	16.0	18.7	13.95	18.3
June	1.26	7.75	3.35	9.69	17.1	18.2	18.70	16.9
July	4.16	4.14	32.20[1/]	7.20	20.5	21.0	24.10[2/]	25.0
Aug.	4.36	3.85	5.80	5.45	16.5	19.1	19.90	16.9
Sept.	1.86	0.85	3.41	4.60	13.7	-	12.00	13.0
Oct.	0.72	0.68	4.91	1.55	6.7	-	6.74	6.4

[1]Propanil period that resulted in a reduction in the treatment of rice fields – one trap adjacent to rice fields produced 97% of the *C. tarsalis* recovered in July, 1967.

[2]Reduction in rice field inspections due to propanil.

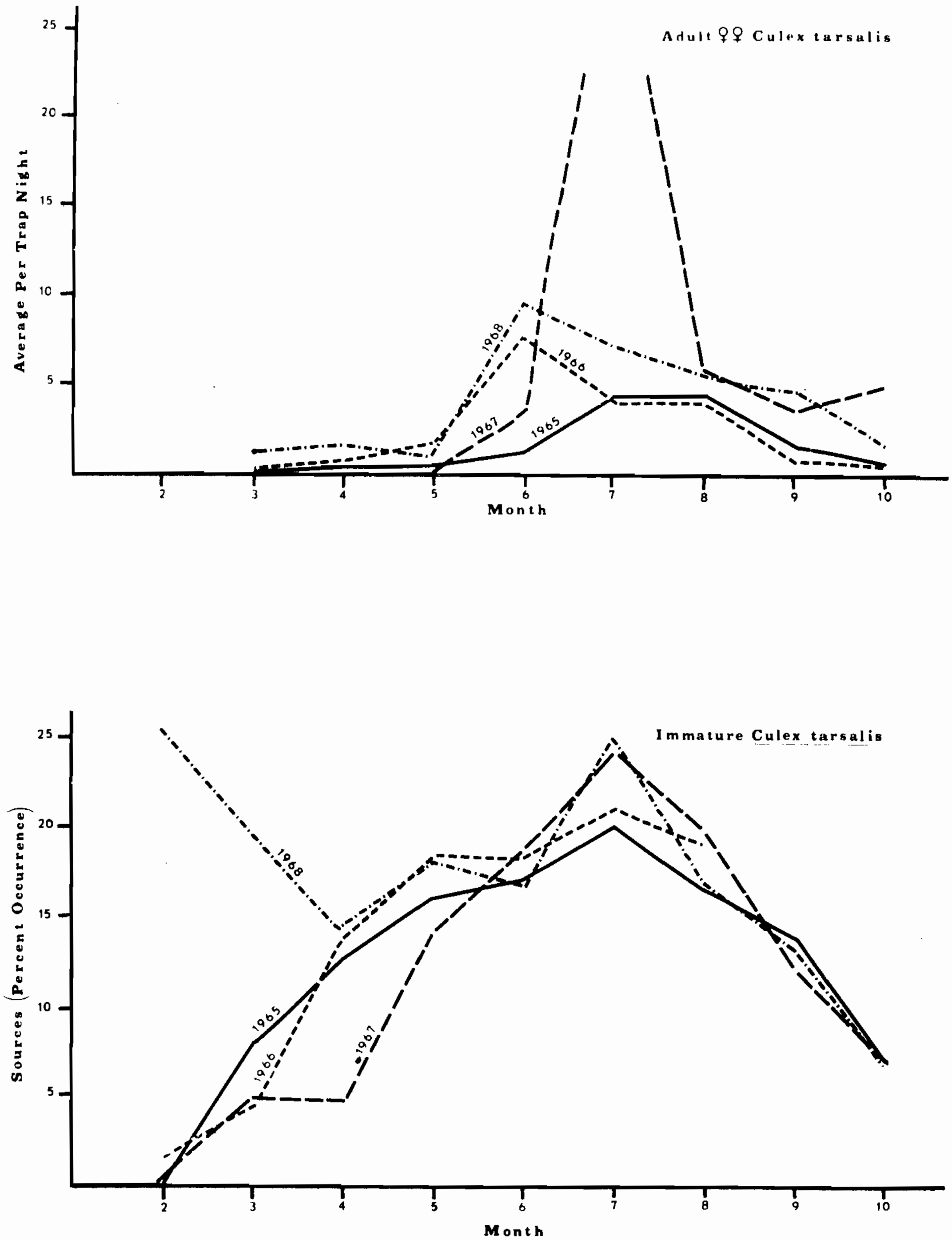


Figure 3. A four-year comparison between *Culex tarsalis* occurrence in all sources inspected and the number of females collected per trap night in eight traps located in the Fresno Westside Mosquito Abatement District.

the most critical influence upon the values obtained. Man-made factors, such as crop sequence, irrigation, and soil intake changes due to cultural practices, are also involved and will influence the production of adult mosquitoes. Light trap data are also influenced by wind, humidity, moonlight (or competing lights), and the physiological condition of the mosquito. In spite of this, the data obtained have certain important characteristics that have been used successfully for population analysis as illustrated in this report.

b. The annoyance factor may be more closely associated with light trap data than with larval data, however, vector potential in the early season seems to be difficult to correlate with light trap data.

c. Day flying species of mosquitoes are not sampled adequately (Haufe and Burgess 1960). Some species may change their flying behavior depending upon age (gonotrophically active physiological state) and while in this state may move toward sources for oviposition and avoid locations where light traps are normally located.

d. Light trap data may reflect the migratory or flight activity of species – which may change during the season.

e. Species that normally do not move very far from their site of emergence are not sampled adequately by traps located in communities. An adequate sample should reflect seasonal variations, trends, and a yearly index.

There is some question about the significance of examining light trap data to determine the prevalent or 'average' population trends over a period of years. Each season the factors influencing trap data are extremely variable and until we can correlate these factors with the sample obtained it would seem wise to examine data as a single unit of information. In other words, determine why 1967 was different than 1968, etc.

2. Immature mosquito sampling data:

a. Larval sampling data are closely associated with the chemical control program (since it is a measure of sources inspected and frequently treated).

b. Larval samples can be correlated with the type of source since each species is associated with recognized environmental conditions.

c. Larval data provide a sensitive measurement of early season occurrence (influx) of mosquitoes.

d. Larval data may provide a clue to abnormal variations in populations, as indicated in the 1968 data.

e. Larval data can be correlated with rainfall or irrigation if adequate records are maintained to show the types of sources (pasture, alfalfa, etc.) or the sources of water (rainfall, irrigation, drainage, etc.).

f. A ratio of the number of positive to negative sources can show several interesting interrelationships between species occurrence and factors that contribute to the work load imposed upon the operators, airspray program, and budget.

g. There is a significant positive seasonal correlation between the occurrence of immature mosquito sources and the light trap data for *C. tarsalis*. *A. melanimon* and *A. nigromaculis* do not show this correlation.

References Cited

Barr, A.R., T.A. Smith, and M.M. Boreham. 1960. Light intensity and the attraction of mosquitoes to light traps. J. Econ. Entomol. 53(5):876-880.

Collett, G.C., J.E. Graham, and I.E. Bradley. 1964. Relationship of mosquito light trap collecting data to larval survey data in Salt Lake County. Mosq. News 24(2):160-162.

Haufe, W.O., and L. Burgess. 1960. Design and efficiency of mosquito traps based on visual response to patterns. Can. Entomol. 92(2):124-140.

Graham, J.E., and I.E. Bradley. 1961. An evaluation of some techniques used to measure mosquito populations. Proc. Utah Acad. Sci. Arts and Letters 39:77-83.

1962. The effects of species on density of mosquito larval populations in Salt Lake County, Utah. Mosq. News 22(3):239-247.

Husbands, R.C. 1954. Mosquito ecology studies in irrigated pastures – progress report. Proc. Calif. Mosq. Control Assoc. 22:43-50.

1955. Ecological interrelationships in irrigated pastures. Proc. Calif. Mosq. Control Assoc. 23:104-105.

1955. Irrigated pasture study – a review of factors influencing mosquito production – weather, ponding and irrigation, and soil moisture. Proc. Calif. Mosq. Control Assoc. 23:112-117.

Husbands, R.C., and B. Rosay. 1952. A cooperative ecological study of mosquitoes of irrigated pastures. Proc. Calif. Mosq. Control Assoc. 20:17-26.

1953. Irrigated pasture mosquito ecology studies – 1952. Proc. Calif. Mosq. Control Assoc. 21:33-37.

Loomis, E.C. 1953. Population trends of *Culex tarsalis* in the Central Valley of California. Proc. Calif. Mosq. Control Assoc. 21:73-76.

1959. The function of larval surveys in the California encephalitis surveillance program. Proc. Calif. Mosq. Control Assoc. 21: 64-67.

Reeves, W.C. 1968. A review of the developments associated with the control of western equine and St. Louis encephalitis in California during 1967. Proc. Calif. Mosq. Control Assoc. 36:65-70.

Thurman, D.C., Jr., R.C. Husbands, E.W. Mortenson, B. Rosay, and J.A. Arnold. 1951. Review of the 1950 studies of mosquitoes in irrigated pastures. Proc. Calif. Mosq. Control Assoc. 19:72-78.

Thurman, D.C., Jr., R.C. Husbands, E.W. Mortenson, and B. Rosay. 1951. Irrigation cycles, mosquito cycles, and generations of *Aedes* mosquitoes in irrigated pastures in California. Communicable Disease Center Bull. (U.S.) 10(11):18-23.

A CORRELATION OF LARVAL SURVEYS AND SOURCE REDUCTION PRIORITIES IN SALT LAKE COUNTY

Keith H. Wagstaff and Kenneth L. Minson

South Salt Lake County Mosquito Abatement District
Midvale, Utah

Source reduction is an important part of any successful mosquito control program. Our abatement program has been improved each year to meet changing conditions. Improvements in source reduction have been related to larval survey procedures. Each year some drainage is accomplished cooperatively with Salt Lake County Flood Control and at their expense. The value of this work to the District in 1968 amounted to over $9,000.00 and for the most part occurred on public domain. Drainage work accomplished by the district is done by hand when workers are not busy with larviciding procedures and also by contract with some private companies.

At present 1967 sources are listed on district maps. The cost of eliminating all sources is prohibitive for a district such as ours that operates on a small budget. For this reason, source reduction priorities must be established. Information obtained from the larval survey is an invaluable tool in enabling the District to establish priorities.

In conjunction with the control program, an intensive larval survey was initiated by the District in 1956, in which a sample of mosquito larvae was taken from each pool found to be producing them. At the time of collection the data, location, size of pool, source of water, number of larvae per dip, and larval instar are recorded. A sample of larvae from each positive source is collected and identified later in the laboratory. Some of the information obtained from the survey is directly responsible for increased efficiency and effectiveness of the mosquito control program in Salt Lake County (Graham, 1959).

The larval survey has been evaluated and expanded over the years as needs arose so that at present considerable data are now collected by field inspectors for each pool found containing mosquito larvae. These data consist of pertinent ecological information such as: (1) associated vegetation, (2) water characteristics, (3) flow of water in pool, (4) degree of shade, (5) depth of water where larvae are found, and (6) air and water temperature. Also, time of day collection is made and type of treatment required for effective control are noted. All sources are routinely checked and are recorded as wet or dry and if wet, whether damp, recently flooded, drying up or no change from previous inspection. These data are in addition to data recorded when the survey was initiated. Very little extra time is required to conduct the survey as necessary observations, collections and notes can be made during the inspection for larvae.

District personnel are approaching source reduction with the attitude that each source in the District can be either completely eliminated or modified so as to retard larval development. During the past year all sources in the District were examined and source reduction procedures, regardless of cost, were outlined for each. At the same time information obtained from the larval survey enabled us to evaluate the mosquito potential of each source. Such items as larval

Figure 1. Chart demonstrates how a portion of the larval survey data is recorded daily. The code used for the chart is: n.c. = not checked

Water Code

1. Dry
2. Soil moist
3. Water level decreasing
4. No obvious change from previous period
5. Water level increasing

Treatment Code

6. Treated with parathion sand core granules

X = Positive for indicated (major) species
Other species written in

Area Code = location of source

AN EXAMPLE OF DATA RECORDING ON LARVAL SURVEY CHART

INSPECTION PERIODS	7/29 - 8/2								8/5 - 8/9								8/12 - 8/16								8/19 - 8/23								8/26 - 8/30							
AREA CODE	WATER	TREATMENT	C. tarsalis	A. dorsalis	A. vexans	C. pipiens	C. inornata	A. freeborni	W	T	C.t.	A.d.	A.v.	C.p.	C.i.	A.f.	W	T	C.t.	A.d.	A.v.	C.p.	C.i.	A.f.	W	T	C.t.	A.d.	A.v.	C.p.	C.i.	A.f.	W	T	C.t.	A.d.	A.v.	C.p.	C.i.	A.f.
7-56	4	6	X			X			4	6				X			4	6				X	X		4								4	6					X	
7-57	3								4	6			X		X		4	6		X			X		4								4	6		X	X	X	X	
7-58	4	6			X				5								4	6		X			X		3								3	6		X	X			
7-59	4	6			X				5								4	6	X				X		3								4	6		X	X		X	
7-60	4	6			X				5								4	6	X				X		3								4	6		X	X		X	
7-61	2								5								5	6	X				X		3								4	6			X		X	
7-62	4								4	6				X			3								5								nc							

density, area of source, water source, associated vegetation, frequency of production, and species identification are utilized in making this evaluation of mosquito potential. Figure 1 demonstrates the method of recording part of the data.

Of the listed sources in the District only 29, or less than 2%, were positive for larvae 50% or more of the time each was inspected. These are considered to be the most important sources and should be eliminated first. Sources producing few mosquitoes are left for later elimination or reduction. Source reduction priorities are established by considering: (1) mosquito potential, (2) accessibility of source, (3) difficulty in obtaining control, and (4) estimated cost of reduction as opposed to cost of long-term treatment.

In most instances the cost of eliminating a source exceeds the cost of treatment. Over a period of time, however, source reduction should be more economical. Sources producing large and frequent broods of *Culex tarsalis* Coquillet and *Aedes dorsalis* Meigen are considered most important.

Culex pipiens (Ludlow) and *Culiseta inornata* (Williston), while very common in the District, are not problems as they seldom bite man in this area. Consequently, those sources producing these species will place low on a source reduction priority list.

Sources that rate high in mosquito potential but are easily accessible and easily and effectively treated are not considered for source reduction measures until sources that are difficult to control are reduced or eliminated.

Eighty-two of the sources routinely inspected by field crews proved negative for larvae the entire season even though each was continuously flooded. These sources will be investigated, and hopefully, information obtained will give an idea as to how other sources can be altered, thus resulting in a reduction in the mosquito potential without the use of insecticides or costly source reduction action.

Summary

Source reduction, although costly, is a part of any successful mosquito control operation. Due to the expense involved and because of a relatively small budget the Salt Lake County Mosquito Abatement District is establishing source reduction priorities by using information obtained from a well-established larval survey program. Consequently, money available for source reduction is spent where it will do the most good.

References Cited

Graham, J.E. 1959. The relation of detailed larval surveys to control efficiency in Salt Lake County. N.J. Mosq. Exterm. Assoc. Proc. 46:119-121.

MOSQUITO LARVAE CONTROL WITH *GAMBUSIA* AND *LUCANIA* FISH IN RELATION TO WATER DEPTH AND VEGETATION[1]

Don M. Rees, David N. Bown and Robert N. Winget

Center for Environmental Biology
University of Utah, Salt Lake City

Gambusia affinis affinis (Baird and Girard) was successfully introduced into Utah in 1931. *Gambusia* are now generally established throughout the state and in some situations are effective in mosquito abatement.

The killifish *Lucania parva* (Baird and Girard) was found to be present in Utah in 1959 at Timpie Springs, Tooele County. The time and method of introduction can only be surmised.

As *Lucania* are reported to feed on mosquito larvae an attempt was made to determine the effectiveness of *Gambusia* and *Lucania* in controlling mosquitoes on marshland bordering the Great Salt Lake, Utah.

In June 1966 five small experimental units, ranging from 0.24 to 0.80 of an acre in size, were constructed on the Farmington Bay Waterfowl Management Area (Figure 1). The habitat of these small units was typical of the surrounding fresh-water marsh, except that the impounded water was maintained at a fairly constant level at depths varying from 2 to 18 inches. An investigation was conducted during 1966 to 1968 to determine some of the factors affecting mosquito larvae production on these experimental units. Part of this investigation was a study of the relative effectiveness of *Gambusia* and *Lucania* in reducing the production of mosquito larvae in relation to different habitats such as water depths and kinds of vegetation.

The water in the experimental units was obtained from the Jordan River via the State Canal. In the units dissolved oxygen concentrations fluctuated between 0 and 5.0 ppm while pH remained between 7.5 and 7.9. Water temperatures ranged from a low of 53°F in May to a high of 75°F in July declining in late September to 63°F. During this study ice, 1 to 4 inches in thickness, covered the experimental units from early December to near the end of February. The water is high in organic material and other pollutants and has a saline content of 0.4% thus limiting to some extent the types of biota inhabiting these marshes.

The major emergent vegetation present in the experimental units are: Olney's bulrush (*Scirpus olneyi* Gray); alkali bulrush (*Scirpus paludosus* A. Nels); hardstem bulrush (*Scirpus acutus* Muhl.); saltgrass (*Distichlis stricta* (Torr.) Rybd.) and cattail (*Typha* spp. L.) (Figure 3).

[1]This study was financed in part by Public Health Service research grant CC-00171 from the National Communicable Disease Center, Atlanta, Georgia.

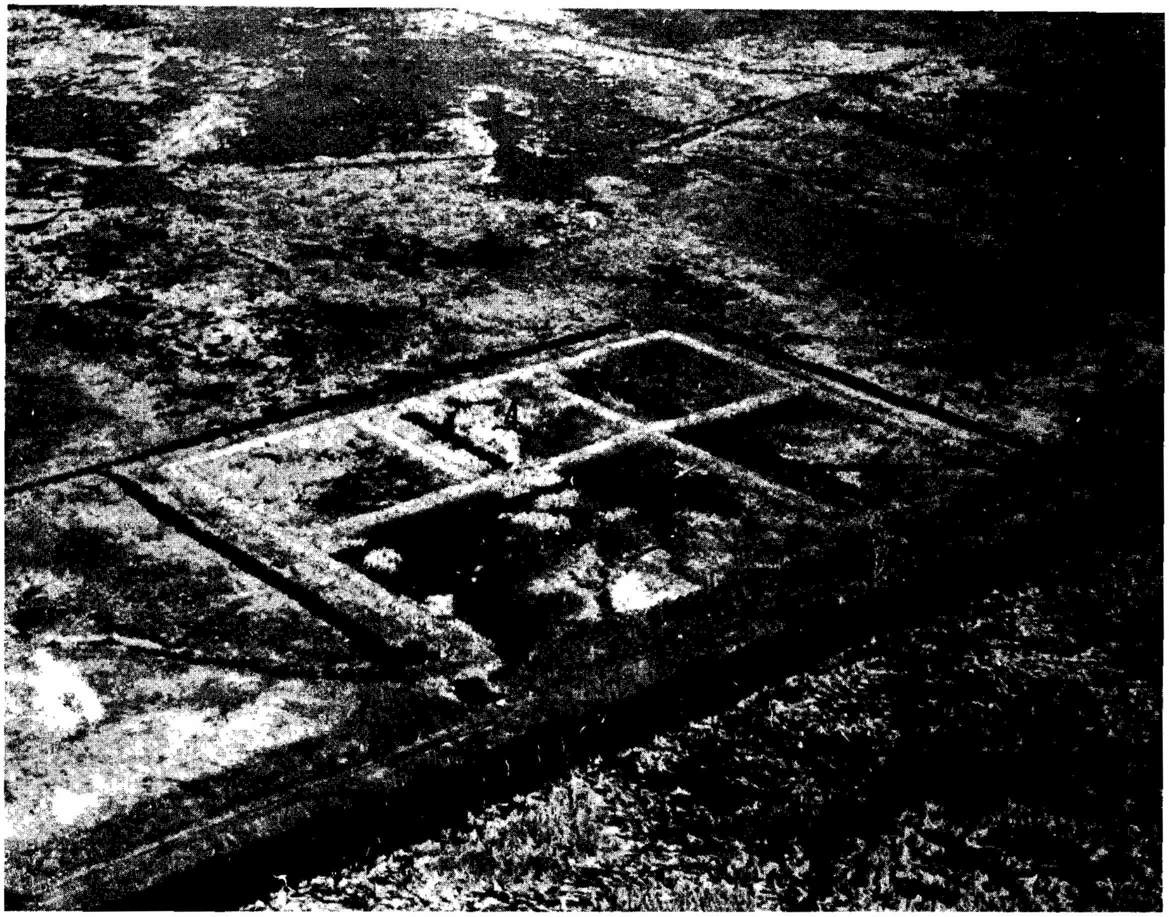


Figure 1. Experimental Units – Farmington Bay Waterfowl Management Area.

Figure 2. Standard wire minnow trap used to sample fish populations in the units.

Species of mosquito larvae present in the experimental units are: *Aedes dorsalis* (Meigen), *Culex tarsalis* (Coquillett), *Culiseta inornata* (Williston) and at times a few *Culex erythrothorax* (Dyar).

Procedures - Units 2 and 3 were selected for stocking with fish and unit 4 was used as a control. Weekly fish samples were taken with a standard wire minnow trap operated for 24-hour periods from the first of June through September during 1967 and 1968 (Figure 2). Weekly mosquito larvae samples were taken from the three units from the second week of July through September of 1966 and from the first week of May through September during 1967 and 1968. Vegetation surveys of the kinds and quantity of each were made in the experimental units in July and September of 1966 and June and September of 1967 and 1968 (Figure 3).

In 1966 no fish were stocked in any of the units. In 1967 units 2 and 3 were stocked with fish while unit 4 was maintained as a control without fish. Unit 2 was stocked with *Gambusia* and unit 3 was stocked with *Gambusia* and *Lucania* as reported by Bown and Rees (1968).

In 1968 no *Gambusia* were introduced into the experimental units, but unit 2 was stocked with *Lucania* and units 3 and 4 were maintained as controls without fish. Unit 4 was modified in July by removal of the cattails from the north half of the unit and six 6-foot square plots of saltgrass were transplanted along the periphery of this half of unit. The saltgrass plots were alternated with open water plots of the same size.

Results and Discussion

It has been reported that mosquito production on these freshwater marshes adjoining the experimental units varies with the type and density of vegetation and with different water depths. This has also been observed on the small experimental units during this study.

Unit 2 - 0.41 acre. Water depths variable from 2 to 10 inches.

In 1966 without fish in this unit there was a seasonal average of 5.41 mosquito larvae per dip (Figure 4).

In 1967, 2000 *Gambusia* were planted during the second week of May and 1000 in the second week of July. The average number of fish per trap increased from 4.0 in June to 113 in September. The seasonal average number of mosquito larvae per dip was 0.47 in 1967. As the number of fish per trap increased there was a corresponding decrease in the number of mosquito larvae per dip with no larvae being taken in the samples after the last week of July (Figure 4). Changes in vegetation were not sufficient to account for the extent of the decline in the number of mosquito larvae. This is demonstrated by the high number of mosquito larvae present in unit 2 during 1966 and 1968.

In 1968 unit 2 was stocked with *Lucania* as follows: 3000, May 21; 3000, June 15; 3000, August 8; and 3000, September 21. The average number of fish per trap increased from 6.0 in June to 13.0 in September. The seasonal average number of mosquito larvae per dip was 3.85 in 1968. In the early part of the season *Lucania* were apparently not present in sufficient numbers to be effective in mosquito control, but later in the season as their numbers increased there was a decline in the numbers of mosquito larvae (Figure 4).

During August and September of 1967 in unit 2 gravid female *Gambusia* were collected most abundantly in the bulrush and cattail with averages of the total number collected of 43% and 33%, respectively. Immature *Gambusia* were most abundant in the saltgrass, comprising more than 44% of the total *Gambusia* taken. During 1968 in unit 2 slightly higher numbers of *Lucania* were collected in the saltgrass than in the bulrush (Bown and Rees, 1968).

During this three-year period the majority of the mosquito larvae found in unit 2 were in areas vegetated with saltgrass or saltgrass mixed with alkali bulrush with water depths from 4 to 8 inches. No larvae were found in open water or cattail plots.

Unit 3 - 0.24 acre. Water depths variable from 4 to 12 inches.

In 1966 without fish in this unit the seasonal average number of mosquito larvae per dip was 2.70 (Figure 5). The majority of the larvae were found in saltgrass and saltgrass mixed with alkali and Olney's bulrush with depths between 4 and 8 inches.

In 1967 *Lucania* were stocked as follows: 630 on May 10; 1000 on May 16 and 2000 on June 16. *Gambusia* entered the unit through the drain from unit 2 and mixed with *Lucania* throughout the unit. The average number of *Gambusia* per trap increased from 0 in May to 74.3 in September and the average number of *Lucania* per trap increased from 0 in May to 48.7 in September. The seasonal average number of mosquito larvae per dip was 0.25 with no larvae taken in sampling after the last week of June (Figure 5). Mixed populations of *Gambusia* and *Lucania* were able to attain sufficient numbers for effective control of mosquito larvae earlier in the season in unit 3 than *Gambusia* alone in unit 2. The extreme vegetation changes from 1966 to 1967 (Figure 3) apparently did not account for the decrease in the number of mosquito larvae in this unit. This is substantiated by the reappearance of large numbers of mosquito larvae in 1968 with similar vegetation composition to 1967.

Most of the larvae found in 1967 were in Olney's bulrush or Olney's bulrush mixed with saltgrass with water depths from 4 to 10 inches. *Lucania* were collected as follows: saltgrass 33%; open water 31%; cattail 18%; and in a mixture of saltgrass and bulrush 14%.

In 1968 no fish were stocked in unit 3. The seasonal average number of mosquito larvae per dip was 2.68 (Figure 5). Most of the larvae were found in Olney's bulrush

Fig. 3 TOTAL PER CENT COVER OF EXP. UNITS

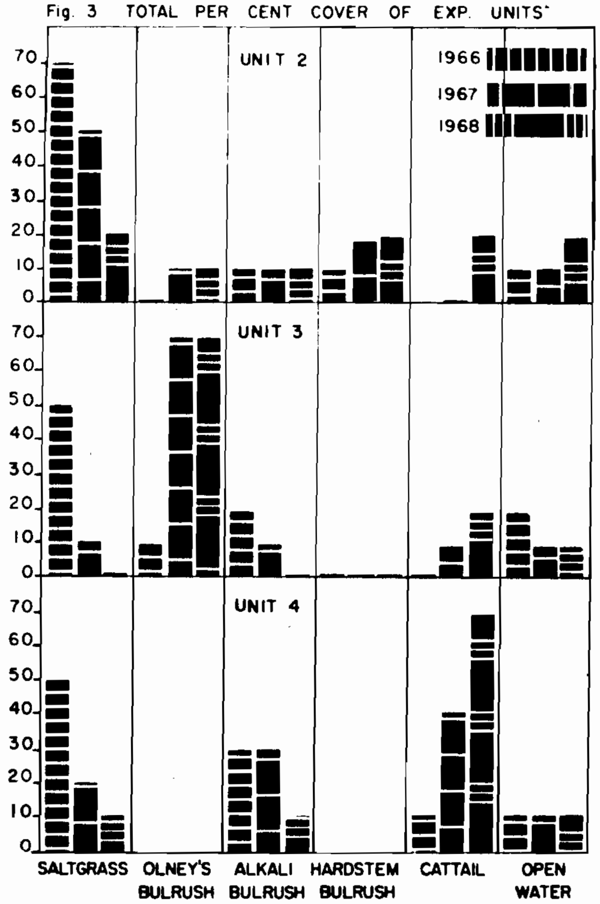


Fig 4 COMPARISON OF MOSQUITO LARVAE AND FISH DENSITIES Experimental Unit 2

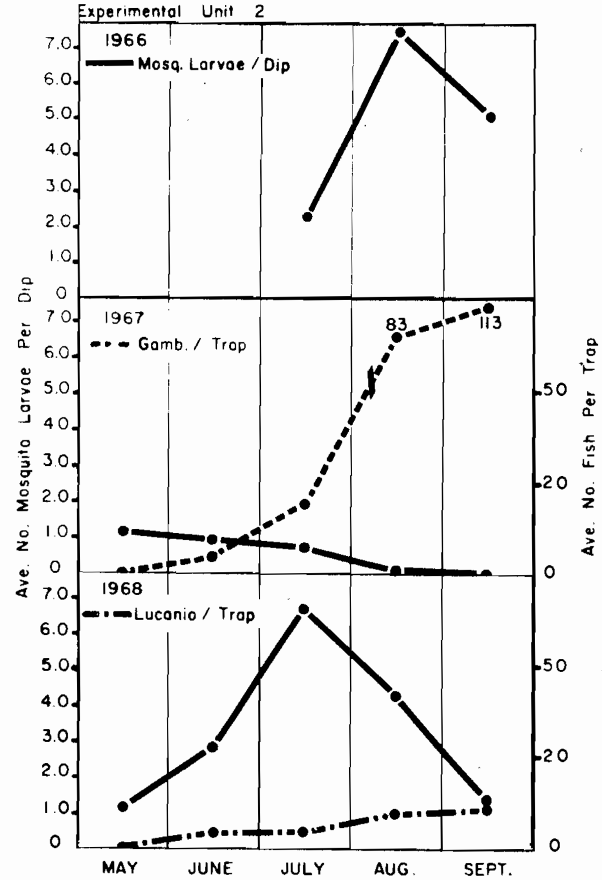


Fig. 5 COMPARISON OF MOSQUITO LARVAE AND FISH DENSITIES Experimental Unit 3

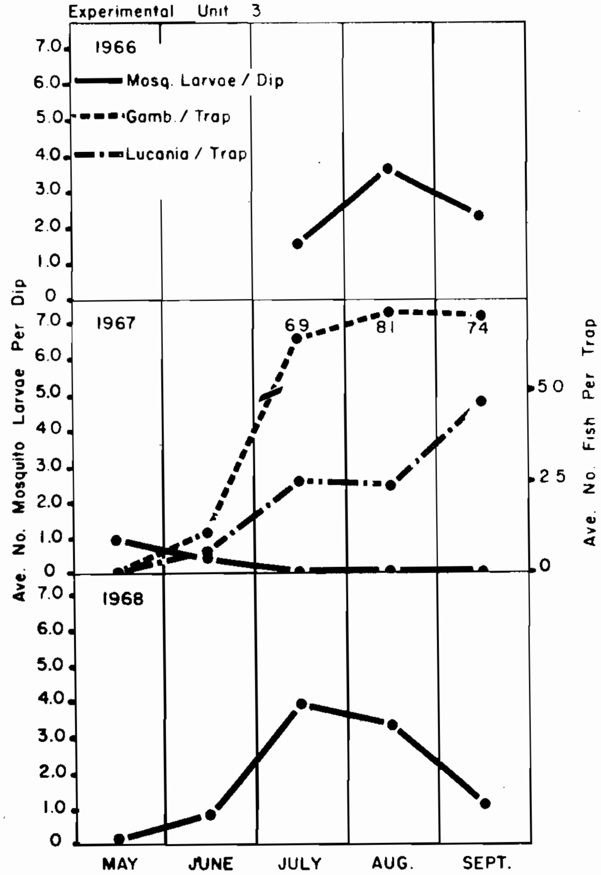
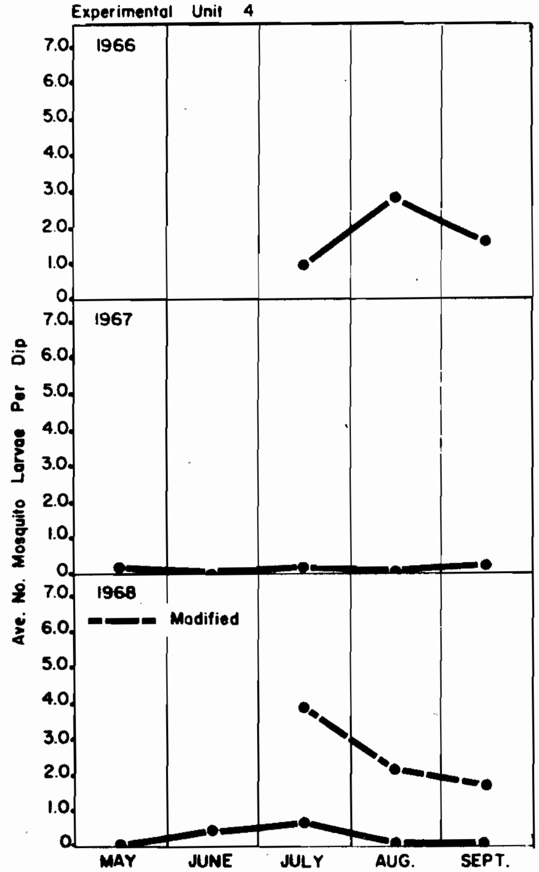


Figure 6 COMPARISON OF MOSQUITO LARVAE DENSITIES Experimental Unit 4



with water depths from 6 to 10 inches. There were only trace amounts of saltgrass remaining in the unit.

Unit 4 - .24 acre. Water depths variable from 2 to 8 inches:

No fish were stocked in unit 4 during the three years of this study.

In 1966 the seasonal average number of mosquito larvae per dip was 1.96 (Figure 6). The majority of the larvae were found in saltgrass and alkali bulrush mixed with saltgrass with water depths from 2 to 6 inches.

In 1967 the mosquito larval production was sporadic and lower than in 1966 with a seasonal average number of larvae per dip of 0.14 (Figure 6). Most of the larvae were found in saltgrass and saltgrass mixed with alkali bulrush which had decreased from 80% of the total cover in 1966 to 50% in 1967 (Figure 3).

In 1968 the number of mosquito larvae per dip was low with an average of 0.25 from the first of May to the last of June. In July, after the cattails were removed from about half of the unit and saltgrass plots were established, the average number of larvae per dip increased to 2.76 in the saltgrass plots and to only 0.35 in the remaining cattail and alkali bulrush areas. No larvae were found in the open water between the saltgrass plots (Figure 6).

Over the three-year period with water depths remaining the same, the decrease in number of mosquito larvae seems to directly parallel the decrease in the amount of saltgrass and alkali bulrush and the increase in the cattails present in the unit. This was established in 1968 when large numbers of mosquito larvae were produced in the saltgrass plots while production remained low in the unmodified half of the unit.

Conclusion

1. *Gambusia* alone and a mixed population of *Gambusia* and *Lucania* effectively reduced and by July 1 eliminated mosquito production at all water depths and in all kinds of vegetation in the units stocked.

2. Apparently, *Lucania* alone were partly responsible for a decline in mosquito production starting the last of July but did not eliminate production by the end of the season in the unit where stocked.

3. The evidence indicates that *Lucania* were unable to increase in sufficient numbers to be completely effective in mosquito abatement in the units where stocked.

4. Apparently, *Lucania* have a higher mortality and lower reproductive rate than *Gambusia* when stocked in these units.

5. In this study neither *Lucania* or *Gambusia* survived the winter of 1967-1968 in the experimental units. It has been observed in other parts of the marsh that a few *Gambusia* are able to survive the winter where conditions are more favorable. Winter kill is undoubtedly a limiting factor in the use of *Gambusia* or *Lucania* for mosquito control in these marshes.

References Cited

Bown, David N., and Don M. Rees. 1968. Proc. Utah Mosq. Abate. Assoc. 21:31-32.

THE DEVELOPMENT OF MIDGE PROBLEMS IN THE SHASTA MOSQUITO ABATEMENT DISTRICT

E.E. Lusk

California State Department of Public Health
Bureau of Vector Control and Solid Waste Management

J.D. Willis

Shasta Mosquito Abatement District, Redding

ABSTRACT

The growing use of waste stabilization lagoons as a method of sewage disposal and the development of lakeside recreational subdivisions have resulted in greatly increased gnat problems in many northern California areas.

During the past three years a series of developments of this type has nearly tripled gnat sources in the Shasta Mosquito Abatement District. *Chaoborus astictopus* Dyar and Shannon, have been responsible for most of the annoyance. It has been necessary for the District, with assistance from the State Health Department, to organize and carry out a series of control operations. A variety of organic phosphate insecticides including fenthion, parathion, methyl parathion and Dursban® have been tested.

Even greater increases in gnat problems are anticipated as a result of projects currently under construction or in the planning stage. The District is planning a study to determine the feasibility of accepting gnat control as a part of its regular operations.

GNAT CONTROL OPERATIONS IN THE SHASTA MOSQUITO ABATEMENT DISTRICT

William C. Hazeleur

Shasta Mosquito Abatement District, Redding

For the past several years we have been experiencing more and more trouble in the Shasta Mosquito Abatement District with gnats and midges. During the past two years over 20% of our service requests have involved gnats rather than mosquitoes. While there may be some mosquitoes involved, people see large swarms of insects and decide that they are all mosquitoes. The possibility of the Shasta MAD undertaking gnat and midge control has been discussed at several meetings of the Board of Trustees.

The problem reached a peak in the spring of 1967 when the City of Redding initiated the use of new sewage lagoons six miles south of Redding. Two months after these ponds went into operation a severe chaoborid gnat problem developed in the surrounding area. The City of Redding was threatened with lawsuits from adjacent property owners and the Shasta MAD became involved in close surveillance of the ponds for our own protection, since many people were mistaking the gnats for mosquitoes. Property owners not only objected to the masses of gnats hatching from the ponds but were also objecting to odors. The City of Redding finally spent in the neighborhood of $200,000 to buy out property owners in the most severely affected areas immediately adjacent to the lagoons.

It was surprising to us that such a condition could develop in ponds that had been in use for such a short time. We worked very closely with the State Department of Public Health, the City of Redding, the Shasta County Health Department, and others to bring the problem under control.

Work carried on at the sewage lagoons was to be a cooperative arrangement between the City of Redding and the Shasta MAD. Much time and effort was spent training city employees on how to properly take Ekman dredge and plankton net samples. City employees were to take samples from the lagoons and deliver them to the District headquarters where they would be processed. When it became apparent that a major emergence of midges was imminent the Shasta MAD would notify the City. The City would then take control measures. Problems arose with this arrangement. Unfortunately it was soon apparent that the City would not be able to carry on the sampling program on a sufficiently regular basis for us to obtain necessary information concerning larval populations.

Problems also developed in actually carrying out control operations. It was necessary for the mosquito abatement district and the Bureau of Vector Control to select the material, make the dosage calculations, and give close supervision during application.

In addition to the problems at the City Sewage Disposal Plant there were a number of other lagoons within the District which were producing midges. The District attempted to handle these in the same manner as they did the Redding lagoons. That is, the lagoon operators were to do the actual control. This approach did not turn out to be satisfactory.

At the June 24, 1968, Board of Trustees meeting the question of whether the District should accept gnat control as a regular part of its operation was discussed. The City of Redding had repeatedly suggested that they would prefer to contract with the Shasta MAD to do the investigative work and carry on control measures as required. It seemed more logical for the mosquito abatement district to do this work than for the other agencies to have to enter into a program of chemical control. The Board of Trustees suggested that the District enter into an immediate general gnat control program. The manager pointed out that it probably would not be possible to carry on a satisfactory program until more information was available on the nature and extent of the problem.

For one thing, we need to know more about the types of sources in the District, the species of gnats in these sources, and, the most important thing, the cost of such a program. The Board of Trustees was willing to raise the tax rate one or two cents for this project but we did not know if this would give the District sufficient funds for a successful control program.

After much discussion of the problem the Board instructed us to proceed with an investigation of the problem and included a little over $10,000 in the budget for this purpose.

It is apparent from previous control trials that efficient midge control will require more detailed knowledge on the biology and ecology of the individual species in the district. Therefore, the district plans to conduct extensive studies on midge populations. A considerable amount of information is already available from previous studies in other areas, however, it is difficult to apply these findings directly to the problems in our district in view of the variety of potential sources.

A series of potential larval habitats was selected for survey and analysis. Included are:

1. Log ponds
2. Drains
3. Sewer ponds
4. Permanent irrigation seepage
5. Creeks
6. Dredger ponds and borrow pits
7. Natural rain water lakes (spring only)
8. Sacramento River seepage

These sites were selected as representative of different habitat types. Data on species composition, larval abundance developmental cycles, and other factors will be recorded. We will attempt to correlate larval occurrence with adult midges from specific problem areas.

PONDWEED – A SUBSTRATE FOR CHIRONOMIDS, ESPECIALLY *PARALAUTERBORNIELLA SUBCINCTA*

Harvey I. Magy[1], Gail Grodhaus[1], James D. Gates[2], and Joe Montez[2]

Most chironomid midge control programs are geared to destroying larvae that develop in the bottom mud of lakes or other bodies of water (benthic midges). It is important that program planners be alert to the fact that significant

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

[2]San Luis Obispo County Health Department.

emergence of midges may arise from other substrates, such as submerged vegetation and algal mats. This has a bearing on the type of control that might be used. Insecticides for benthic midges can be formulated so that they descend to the bottom and can be applied at a pounds-per-acre rate; whereas midges on vegetation in deep water must be treated with formulations that disperse the toxicant throughout the entire volume of water and which have to be applied at a parts-per-million rate. Volumetric rates required to kill larvae tend to be costly, and may also approach toxicity levels lethal to fish.

From 1965 to 1967 the midge population at Laguna Lake, San Luis Obispo County, California was studied. This 150-acre lake, most of which is about 8 feet deep, is formed by a natural swale filled by runoff water from surrounding hills. People living in subdivisions built adjacent to the lake had complained bitterly to the San Luis Obispo City Council and the County Health Department about adult midges.

It was learned that the principal pest species at Laguna Lake is *Paralauterborniella subcincta.* This species is one of the smaller chironomids, small enough to pass easily through window screens, and it is strongly attracted to lights. At times, *P. subcincta* could be observed in enormous numbers on buildings and shrubbery. Unfortunately, the residential development is situated on the south shore of the lake, and in this direction the shoreward flight of newly emerged midges is aided by strong prevailing winds.

It is believed that this is only the second report of nuisance caused by a member of the genus *Paralauterborniella.* Gerry (1954) has described an outbreak of *P. elachista* (=*Apedilum elachistus*) from a brackish pond in Massachusetts.

The ecology of Laguna Lake is profoundly influenced by the growth of aquatic weeds, especially sago pondweed (*Potamogeton pectinatus*). The abundant growth of this plant is extremely favorable to the development of *Paralauterborniella,* whose larvae live attached to the submerged vegetation. Not only does the presence of pondweed provide a large surface area for attachment of midge larvae, but it also creates certain problems with regard to midge sampling.

During the height of its growth, mid-July through September, the pondweed covers approximately two-thirds of the lake, occupying the entire middle portion. At this time the filamentous stems and leaves extend from the bottom to the surface in a tangled mat, originating from a rhizomatous root system in the mud. The tips of the stems, bearing fruiting spikes, project out of the water. Just below the surface, the mat is so dense as to practically eliminate wave action. At the end of the growing season the mat disintegrates. Growth is resumed in the spring, presumably from sprouting tubers and seeds. In May or June the new growth becomes visible as the filaments approach the surface. The only section of the lake free of pondweed, or of any other vegetation, is a channel at least two feet deeper than the rest of the lake along one shore. It is believed that this deeper water prevents sufficient light penetration for the growth of rooted plants.

At full growth the vegetation probably interferes with the movement of fish that might otherwise prey on midge larvae in the middle of the lake. On the other hand, there are predaceous insects, especially damselfly naiads, living in the mat. The shade created by the vegetation probably decreases the production of phytoplankton, however, there appears to be an abundance of periphyton and pondweed pollen, both of which are potential food items for midge larvae.

In addition to sago pondweed, the vegetative mat includes patches of other species of pondweeds and of filamentous algae. Along the margin of the lake there are stands of swamp knotweed (*Polygonum coccineum*) and tule (*Scirpus acutus*). The submerged parts of these plants do not seem to harbor midge larvae in appreciable numbers.

The infestation of sago pondweed has recurred each year since 1965. In 1968 we arranged for Donald L. Rohe, of the Bureau of Vector Control and Solid Waste Management, to take monthly aerial, infra-red photographs of the development of the pondweed. These photographs have confirmed our observations as to the seasonal growth of the mat, and clearly show the area covered. We will use this information to encourage the City of San Luis Obispo to consider undertaking weed control.

To study seasonal changes in the midge population we established a schedule for taking a series of samples at regular intervals – weekly during most of 1965, and biweekly during 1966 and 1967. Adult midges were collected with two American model mosquito light traps. (However, only one trap was used throughout the study.) Larvae were collected with an Ekman dredge and with a scoop dredge (similar to the one described by Anderson et al., 1964), both of which take a $\frac{1}{4}$-ft^2 sample of substrate. The dredge samples were taken at six stations, three samples per station. These samples were washed through a 32-mesh sieve of the type described by Bay (1965). The specimens from the light traps were emptied into 80% alcohol. The washed dredge samples, in water, and the light samples, in alcohol, were spread onto a counting tray. This tray was developed especially for midge sampling by Ernest C. Bay of the University of California, Riverside. With this device one counts only the specimens lying in preselected grid-units, and from these counts the collection totals are estimated. Representative subsamples are removed from selected grid-units and saved for identification.

The results of the light trap sampling of 1965 are summarized in Figure 1, which shows the weekly totals of all species collected by trap No. 1. From the subsample identifications a summary of relative abundance has been prepared for both light trap and dredge collections (Table 1). For simplification the chironomids have been listed by genera. *Paralauterborniella* included the single species, *subcincta.*

Table 1. Relative proportions[1] of specimens collected at Laguna Lake by light trap and dredge May 19 through October 20, 1965.

Date	*Paralauterborniella* Light trap	*Paralauterborniella* Dredge	*Chironomus* Light trap	*Chironomus* Dredge	*Tanytarsus* Light trap	*Tanytarsus* Dredge	*Cricotopus* Light trap	*Cricotopus* Dredge	*Procladius* Light trap	*Procladius* Dredge	Other Chironomidae Light trap	Other Chironomidae Dredge	Other Diptera[2] Light trap	Other Diptera[2] Dredge
5-19	0	0	IV	II	0	II	I	I	0	II	0	I	I	I
5-26	0	0	IV	III	0	I	I	0	0	I	I	I	I	I
6-2	I	0	III	II	I	I	I	0	0	II	I	0	I	I
6-9	0	0	IV	III	I	I	0	0	0	I	I	I	I	I
6-16	0	0	III	III	I	I	0	I	0	II	I	I	I	0
6-23	0	0	III	III	I	I	0	0	0	I	I	I	I	0
6-30	II	0	II	III	I	0	0	I	0	II	I	0	0	0
7-6	I	0	IV	II	0	I	0	0	0	II	I	I	0	I
7-14	III	0	II	III	I	I	0	I	0	I	I	I	0	I
7-20	IV	0	I	III	I	I	0	I	0	I	I	I	0	I
7-30	III	0	II	III	0	II	0	0	0	I	I	I	0	0
8-5	III	0	II	II	0	I	0	I	0	II	I	0	0	0
8-11	III	0	I	IV	I	I	I	0	0	I	I	I	0	0
8-18	IV	0	I	IV	0	I	0	I	0	I	0	0	0	0
9-8	IV	0	I	III	0	I	0	I	0	II	I	I	0	I
9-22	III	I	I	II	0	I	0	I	0	II	I	I	I	I
10-6	II	I	I	I	I	I	I	0	0	II	I	I	I	I
10-20	II	0	I	II	I	I	0	0	0	II	I	I	I	I

[1] 0 = not collected; I = trace to 25.0%; II = 25.1% to 50.0%; III = 50.1% to 75.0%; and IV = 75.1% or more.

[2] This category includes families of Diptera, other than Chironomidae, that contributed to the total light trap and dredge counts. The most prevalent insect in this category was the chaoborid, *Chaoborus astictopus*.

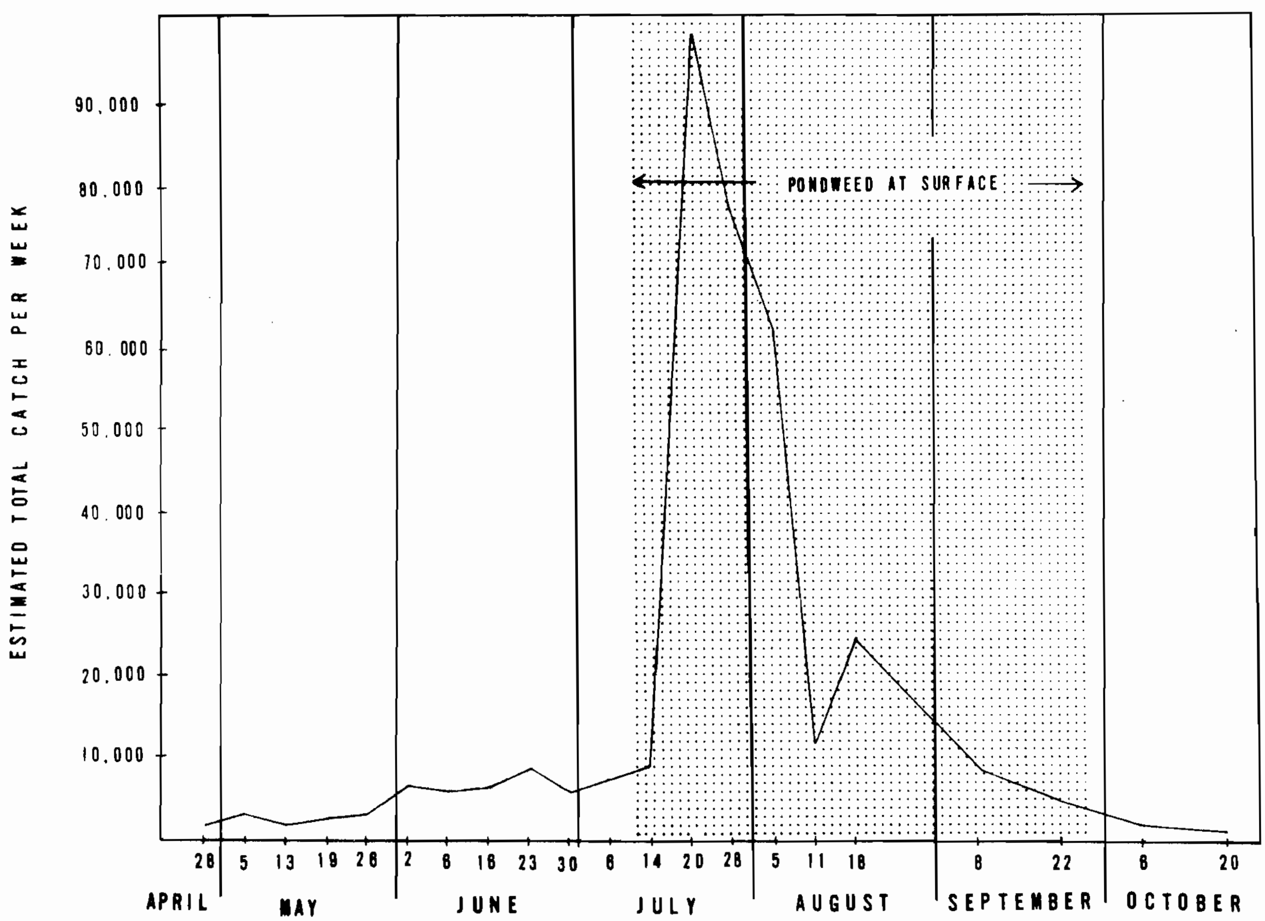


Figure 1. Midges collected by light trap no. 1, Laguna Lake, California, 1965 (with duration of pondweed mat also indicated).

The other genera that were considered important enough to list separately (*Chironomus, Tanytarsus, Cricotopus,* and *Procladius*) each consisted of more than one species.

For the most part the light trap and dredge samples are not in agreement with respect to the relative proportions of the various genera of midges collected, as indicated by Table 1. This lack of correspondence was especially noticeable during the period when the light trap catch was at a peak (mid-July and early August). For example, on July 20, the estimated light trap total was 97,000 midges, approximately 88% *Paralauterborniella;* whereas the dredge collected no *Paralauterborniella* on this date. When the light trap was capturing mostly *Paralauterborniella,* the dredge was collecting a preponderance of *Chironomus* or *Procladius.* After this discrepancy was noted a special effort was made to determine its cause. Visual observations during July, 1965, confirmed that the onshore midge population was composed primarily of *Paralauterborniella* as indicated by the light trap. Further observation revealed that this midge was emerging almost exclusively from the pondweed mat. Special collections from pondweed (taken with a dip-net during August, 1965) contained larvae of *Paralauterborniella* and *Cricotopus* and pupal exuviae of *Paralauterborniella, Chironomus, Tanytarsus, Cricotopus,* and *Procladius.* The collections of exuviae indicate that benthic species, as well as plant-inhabiting species, are able to emerge through the mat. In 1966 we suspended strips of plastic netting in the lake as artificial substrate for midge larvae. In June, after the strips had been in place for five weeks, we collected the following genera from them: *Paralauterborniella, Chironomus, Tanytarsus, Cricotopus, Corynoneura, Psectrocladius, Procladius,* and *Ablabesmyia.* Further study will be necessary before we can claim that any of these collecting methods is consistent enough to provide an index to relative population numbers. However, any of these techniques would have been superior to the dredge, which we believe only collects plant-inhabiting larvae when they are accidentally shaken loose as the dredge descends to the bottom.

As a means of determining the relative seasonal abundance of adult midges, the light trap is probably an adequate device. Our light traps generally took the same species that could be collected with an aerial net or with an aspirator around homes near the lake. There were periods when the light trapping did not reveal the presence of species known to exist as larvae, but we believe that this was because the adults of these species tended to stay close to the shoreline or their larvae underwent protracted development between emergences.

Paralauterborniella clearly dominated the light trap catch of 1965 and 1966. In 1965 this midge first appeared on June 2 and was dominant (comprising more than 50% of the weekly catch) from July 14 until October 20, the last collection date of the year. In 1967 it appeared first on March 27 and was dominant from June 16 until August 7, when collecting was terminated.

During 1965 and 1967 the total light trap catch underwent a sharp rise in mid-July, reflecting the abundance of *Paralauterborniella.* In 1966, when *Paralauterborniella* was considerably less abundant, there was no distinct peak. The emergence season appeared to end in October, 1965 and in September, 1966.

The light trap sampling provided some information on certain chironomids in addition to *Paralauterborniella. Chironomus, Tanytarsus,* and *Cricotopus* adults were collected throughout the study. Of these, *Chironomus* was the most frequently collected genus. *Procladius* appeared briefly in the light trap samples during March-May, 1966 and June, 1967.

From the light trapping we could not determine how many generations of *Paralauterborniella* emerged. Probably there was considerable overlapping. Specimens reared at room temperature in the laboratory developed rapidly Four batches of larvae were reared from eggs deposited by field-collected females. The minimum time from oviposition to adult ranged from 15 to 18 days

The ecological study of midges of rice fields by Darby (1962) has revealed much pertinent information on *Paralauterborniella.* This genus was the second most prevalent category of midges collected in the rice fields. The field contained a variety of aquatic plants in addition to rice. *Paralauterborniella* larvae were listed as abundant on the surface of unspecified submerged plants and moderately abundant on floating algae (*Gloeotrichia*) and on the surface of the mud where rice was scarce or absent. Darby indicated that the submerged plants included *Echinodorus, Alisma, Sagittaria, Najas,* and *Zannichellia. Potamogeton* was evidently not present. *Paralauterborniella* larvae were observed to construct relatively short tubes of silk and bits of algal debris. The principal food was believed to be diatoms.

We seldom collected *Paralauterborniella* larvae at the mud surface. However, most of our samples were taken in water much deeper than that of a rice field.

Darby observed that *Paralauterborniella* males often swarm during daylight hours. He also noted that early evening was the period when most adults appeared at lights. Our experience agrees with both of these observations.

There remain a number of unsolved problems having to do with the midge nuisance at Laguna Lake. Our understanding of midge ecology would improve if we could develop sampling techniques for plant-inhabiting larvae. We especially need to determine depth relations of larvae living in the pondweed and to investigate the effects of fish predation within and outside of the weedbed.

Summary and Conclusions

1. Annually an extensive mat of sago pondweed, *Potamogeton pectinatus,* develops in Laguna Lake. From about mid-July through September this plant is at full growth, extending from the bottom to the surface.

2. Excessive numbers of chironomid midges were found to be a nuisance to residents of a subdivision adjacent to the lake. Midges were especially abundant during July and August. During periods of peak abundance the onshore midge population consisted primarily of a single species, *Paralauterborniella subcincta.*

3. It is believed that light trapping gives a rather good indication of the prevalence of various species of midges emerging from the lake. The maximum number of midges collected by this method was estimated at 97,000 for a one-week period. On this occasion the catch consisted of approximately 88% *P. subcincta.*

4. *P. subcincta* larvae were observed living attached to the submerged leaves and stems of pondweed. These larvae were seldom collected by dredging. Quantitative sampling procedures for plant-inhabiting larvae must be developed before it will be possible to study the abundance and distribution of the aquatic stages of such midges.

5. Midges whose larvae are primarily benthic, including *Chironomus* and *Procladius*, were collected consistently by dredging. However, these genera did not appear to constitute a major nuisance at Laguna Lake.

6. Techniques ordinarily employed for the control of benthic midge larvae may not succeed in lakes where the offending species are associated with aquatic vegetation.

Acknowledgment

We greatly appreciate the advice of Dr. Ernest C. Bay, with whom we consulted frequently during this study.

References Cited

Anderson, L.D., E.C. Bay, and A.A. Ingram. 1964. Studies of chironomid midge control in water-spreading basins near Montebello, California. Calif. Vector Views 11:13-20.

Bay, E.C. 1965. A plastic sieve for separating aquatic bottom fauna. Calif. Vector Views 12:58-59.

Darby, R.E. 1962. Midges associated with California rice fields, with special reference to their ecology (Diptera: Chironomidae). Hilgardia 32:1-206.

Gerry, B.I. 1954. Ecological conditions which influence control of mosquito-like nuisance pests (Tendipedidae). Mosquito News 14:145-149.

ATTRACTION OF *HIPPELATES* EYE GNATS AND OTHER MINUTE DIPTERA TO BAITS AND MAN WITH CONSIDERATIONS ON COMPETITIVE DISPLACEMENT BY EXOTIC NON–PROBLEM SPECIES[1]

E.F. Legner

Department of Biological Control
University of California, Riverside

[1]This study was supported under Grant No. GM 12496 of the National Institutes of Health, United States Public Health Service, and the Coachella Valley Mosquito Abatement District, Thermal, California.

The principle of competitive displacement whereby one species of organism outcompetes or replaces another has been reviewed recently by DeBach (1966), Flanders (1966), and Turnbull (1967). The phenomenon was first demonstrated by Gause (1934) for protozoans, while DeBach and Sundby (1963) illustrated its action with certain species of parasitoid insects attacking citrus scale insects. Turnbull (1967) emphasized that in order for displacement to occur, the competing organisms must necessarily be very closely related. DeBach (1964), discussing the employment of the competitive displacement principle as a biological control tool, suggested that closely related but nonproblematic species of *Hippelates* might be introduced into areas where noxious species occur, with the purpose of reducing the latter through coexistence or eliminating them by displacement.

Earlier efforts at biological control of *Hippelates* have stressed the importation of exotic natural enemies (Bay and Legner, 1963; Legner and Bay, 1965; Legner, 1967; Legner et al., 1966). Coincident with foreign explorations particular attention was paid to the habits of local *Hippelates* species in the various exploration sites. Preliminary findings (Legner and Bay, 1965) showed that various degrees of aggressiveness and activity existed within a single species, some forms of which were even reproductively isolated from others suggesting that they were siblings or even separate species. The present discussion describes some of the charateristics of certain predominant *Hippelates* and associated species over widely separated Eastern and Western Hemispheric sites, their relative abundance being determined from egg bait and net collections, and presents the possibilities for their introduction in California for competitive displacement or coexistence with noxious species. The principal target species under consideration are *Hippelates collusor* (Townsend), *H. robertsoni* Sabrosky, and *H. impressus* Becker (Mulla and March, 1959).

Methods and Materials

The principal survey tool was the bait trap (Fig. 1) which was armed with two size 000 (10 x 25 mm) gelatin capsules containing powdered egg, and a plug of cellucotton to anchor the capsules to the bottom of the trap. These traps were suspended randomly throughout the survey areas in the shade from bushes and trees, and they were activated by the addition of 200 ml H_2O. Insects were most strongly attracted from the third through the sixth days after activation when temperatures ranged from 22-32°C. Predation of trap contents by ants was precluded by the addition of axle grease to the branch from which it was suspended. Attracted insects entered the trap openings through differential screens of 16 mesh/in, made their way upwards through an inverted funnel and into the collection receptacle at the top (Fig. 1).

Other survey methods to determine the existence of additional species included collections made from the windshield of automobiles in which rotting egg baits had been placed (Legner and Bay, 1965), net sweeps of the ground vegetation, and directly from the air immediately surrounding the head of humans. In the latter case, the author, his wife, and daughter participated in all areas, and references to attraction intensity include observations on all three individuals.

Collected specimens were stored in 75% ethanol. Identifications of Agromyzidae, Anthomyzidae, Chloropidae, Chyromyidae, Dolichopodidae, Milichiidae, Muscidae, Sepsidae, Sphaeroceridae, and Trixoscelididae were made by C.W. Sabrosky; of Drosophilidae, Ephydridae, Ceratopogonidae, and Phoridae by W.W. Wirth; of Empididae, Otitidae, and Thyreophoridae by G. Steyskal; and of Sciaridae by A. Stone of the U.S. Department of Agriculture, U.S. National Museum. I am grateful for this assistance.

Surveys were conducted during the summer months in each locality, unless otherwise indicated. Checks with local scientists generally indicated that the survey intervals were at the time of maximum *Hippelates* abundance in the respective areas, which generally corresponded to mid- or late summer. Areas covered included diverse sites in North, Central, and South America, the West Indies, Europe, the Middle East, and Africa.

Results

Relative Numbers of Species Trapped and Distribution - The relative attraction of insect species in the size range of *Hippelates* to rotting egg bait traps at the various foreign collection sites are presented in Table 1. Species collected throughout southern California are shown in Table 2.

It is apparent that Chloropidae were generally the most numerous species trapped in both Western and Eastern Hemispheric sites, with *Hippelates* in the west and *Oscinella* and *Elachiptera* in the east being most prominent. *Hippelates* was absent from the Eastern Hemisphere, which bore out previous conclusions by Sabrosky (1941 and 1951).

The most widely distributed species in America were *Hippelates pusio*, *H. dorsalis*, *H. peruanus*, and *Milichiella lacteipennis;* while *Oscinella frit* predominated in Europe and the Middle East, and *O. dimidiofrit* Becker in E. Africa (Tables 1 and 2).

There were more *Hippelates* species trapped in the West Indies than in any other region. As one proceeded north or south of this region, other genera of Chloropidae replaced *Hippelates*, although none of them was as strongly attracted to rotting egg as *Hippelates* themselves. Some distinct species prevailed in South America (Table 1).

Samples gathered by net sweeps of ground vegetation often produced greater proportions of certain species than the bait traps, enabling some estimation of weak or strong attraction to the baits. Some species were so scarce that only the most casual relationship to the traps was indicated (e.g., Ceratopogonidae, Muscidae, Otitidae, etc.).

Attraction to Man - For the most part, only *Hippelates* species were strongly attracted to the vicinity of the human head. A very slight attraction was shown by unidentified

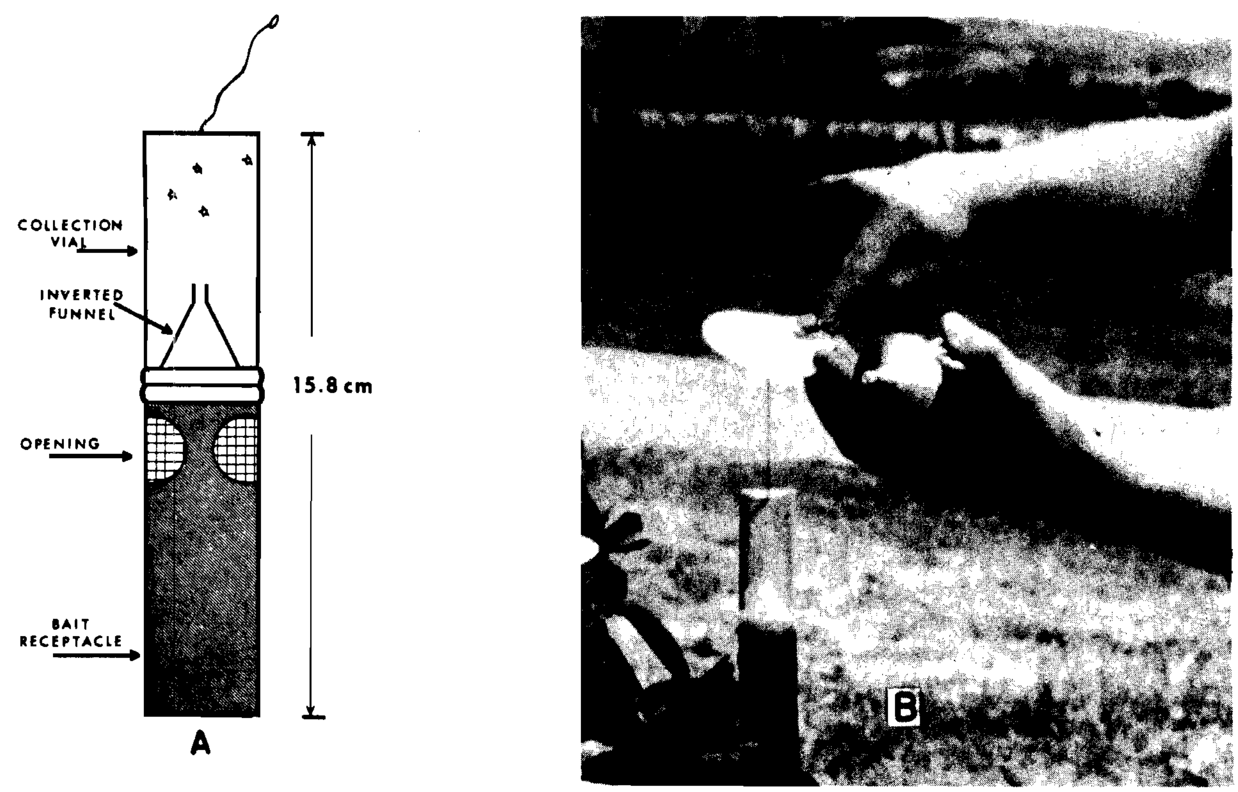


Figure 1. Bait trap used in survey for *Hippelates* species: (a) basic design, (b) application of grease to ant barrier disc above the trap located in tree foliage.

species of *Conioscinella* at several American sites, and a moderate attraction was shown by *Oscinella aharonii* Duda in the Middle East. There was no observed attraction to man of any of the other species trapped in portions of the Eastern Hemisphere (Table 1).

Two species which stand out as being very strongly attracted to humans are *Hippelates collusor* in the Southwestern United States and *Hippelates pusio* in Bermuda. Other West Indian and American forms of *H. pusio* did not demonstrate the same degree of aggressiveness (Legner and Bay 1965) (Tables 1 and 2). Of moderate concern were *H. flavipes* in the West Indies, *H. parviseta* (Mall.) in Uruguay, *H. australis* Sabrosky in Chile, and *H. dorsalis* and *H. robertsoni* in California. Other species listed in Tables 1 and 2 were at the most only very weakly attracted to humans.

Behavioral Peculiarities of Some Hippelates and Chloropid Species - The *Hippelates* species that I have observed in North America and the West Indies were many times more aggressive than any found in South and Central America, or chloropids in Europe and Africa. From conversations with local residents in the respective collection sites of South and Central America, I learned that only occasionally do "gnats" congregate about the eyes and ears, although some areas in northern Peru and the Mato Grosso Region of Brazil apparently harbor localized noxious species.

The Chilean *Hippelates australis* was perhaps the most interesting of all species encountered. It is very strongly attracted to rotting egg bait and foodstuffs, but demonstrates only a weak attraction to mucous areas of the head. The density of *H. australis* seems to increase as one proceeds south of Santiago, until around Valdivia with 80+ in of rainfall. This is the only chloropid species that was ever observed to imbibe rotten egg bait directly. If a droplet were placed on a flat surface, scores of individuals would form a ring around it, extending a rather long proboscis that measured about 1/3 body length. They would then proceed to sponge (or suck) the droplet dry, like so many elephants around a water trough.

The predominant Uruguayan species, *Hippelates parviseta* (Mall.), had the habit of settling on one's arms and legs in small numbers not exceeding five individuals, but rarely reached the vicinity of the head. This species appears to be extremely tolerant of wind, and could be collected from the arms and legs and around rotting egg bait during brief intervals between wind gusts exceeding 15 mph. The attraction to rotting egg appeared to be quite passive, and there was no noticeable feeding on it.

In northern Uruguay and southern Brazil *Diplotoxa glabricollis* (Thomas) and *Hippelates annulatus* Enderlein had the curious habit of collecting in the small hollows of hoofprints made by wild pigs and range livestock around river banks. The region is characteristically swept by a light breeze that forces many small insects to seek refuge. Such was probably the case with these species that, in spite of the protection afforded by the hoofprint craters, still found it

Table 1. Diptera under 4 mm long attracted to rotten egg baits at diverse sites in the Americas, the Mediterranean area, and East Africa.

Locality & Sample Period	Family & Species	Relative Attraction to Baits (%)	Attraction Intensity baits	Attraction Intensity man
Jamaica				
Montego Bay				
June-Sept. 1963	Chloropidae			
	Conioscinella spp.	15.6	W	W
	Hippelates apicatus Malloch	4.2	W	W
	H. dorsalis Loew	0.3	W	M
	H. flavipes Loew	2.0	W	W
	H. peruanus Becker	3.3	W	O
	H. pusio Loew	51.6	S	M
	Hippelates nov. sp.	22.1	M	W
	Milichiidae			
	Desmometopa sp.	0.3	W	O
	Otitidae			
	Acrosticta apicalis (Williston)	0.3	W	O
	Phoridae			
	Genus sp. (?)	0.3	W	O
Discovery Bay				
June-Sept. 1963	Chloropidae			
	Conioscinella spp.	75.1	W	W
	Hippelates tibialis Duda	19.5	W	O
	Otitidae			
	Euxesta nov. sp.	5.4	W	O
Spanish Town				
June-Sept. 1963	Ceratopogonidae			
	Dasyhelea sp.	0.2	W	O
	Forcipomyia sp.	0.7	W	O
	Chloropidae			
	Conioscinella spp.	0.7	W	W
	Hippelates currani Aldrich	0.5	W	O
	H. dorsalis Lw.	3.4	W	O
	H. flavipes Lw.	4.4	W	W
	H. peruanus Beck.	1.0	W	O
	H. pusio Lw.	86.0	S	M
	Hippelates nov. sp.	0.7	W	O
	Ephydridae			
	Hydrellia sp.	0.5	W	O
	Milichiidae			
	Milichiella lacteipennis (Loew)	0.7	W	O
	Otitidae			
	Acrosticta apicalis (Williston)	0.5	W	O
	Sphaeroceridae			
	Leptocera sp.	0.7	W	O
May Pen				
June-Sept. 1963	Chloropidae			
	Hippelates peruanus Becker	3.0	W	O
	H. pusio Lw.	97.0	S	M

Locality & Sample Period	Family & Species	Relative Attraction to Baits (%)	Attraction Intensity baits	Attraction Intensity man
Yallas June-Sept. 1963	Chloropidae			
	Hippelates currani Ald.	0.6	W	O
	H. flavipes Lw.	3.0	W	M
	H. peruanus Beck.	0.6	W	O
	H. pusio Lw.	66.0	S	M
	Hippelates nov. sp. (?)	3.6	W	O
	Milichiidae			
	Desmometopa tarsalis Loew	21.9	W	O
	Desmometopa sp.	2.5	W	O
	Milichiella lacteipennis (Lw.)	1.8	W	O
West Kingston June-Sept. 1963	Ceratopogonidae			
	Forcipomyia sp.	0.3	W	W
	Chloropidae			
	Conioscinella sp.	0.9	W	O
	Hippelates apicatus Mall.	0.6	W	O
	H. dorsalis Lw.	0.3	W	M
	H. flavipes Lw.	2.1	W	O
	H. peruanus Beck.	2.1	W	O
	H. pusio Lw.	91.3	S	M
	Hippelates nov. sp. (?)	1.5	W	O
	Phoridae			
	Genus sp. (?)	0.3	W	O
	Sphaeroceridae			
	Leptocera sp.	0.6	W	O
Bermuda, W.I. Sept. 1963	Chloropidae			
	Hippelates pusio Lw.	100.0	S	S
Puerto Rico Aguadilla March-Sept. 1963	Chloropidae			
	Hippelates flavipes Lw.	57.0	M	W
	Empididae			
	Genus sp. (?)	14.4	W	O
	Milichiidae			
	Milichiella lacteipennis (Lw.)	28.6	W	O
Isabella March-Sept. 1963	Chloropidae			
	Conioscinella sp.	2.0	W	O
	Hippelates dorsalis Lw.	2.0	W	W
	H. flavipes Lw.	8.2	W	W
	H. peruanus Beck.	52.2	M	O
	H. proboscideus Will.	1.0	W	O
	H. pusio Lw.	29.6	M	M
	Chyromyidae			
	Aphaniosoma sp.	2.0	W	O
	Otitidae			
	Euxesta eluta Loew	3.0	W	O
Rio Piedras March-Sept. 1963	Milichiidae			
	Milichiella lacteipennis (Loew)	100.00	W	O
Caguas March-Sept. 1963	Chloropidae			
	Conioscinella sp.	61.6	W	W
	Hippelates flavipes Lw.	27.0	W	W
	Hippelates nov. sp.	7.7	W	O
	Milichiidae			
	Milichiella lacteipennis (Loew)	3.7	W	O
Maricao March-Sept. 1963	Chloropidae			
	Conioscinella sp.	17.7	W	O
	Hippelates peruanus Becker	70.5	W	O
	Milichiidae			
	Desmometopa sp.	11.8	W	O
Aibonito	Milichiidae			
	Desmometopa sp.	20.0	W	O
	Milichiella lacteipennis (Loew)	80.0	W	O
Ponce March-Sept. 1963	Chloropidae			
	Hippelates flavipes Lw.	13.2	M	W
	H. pusio Lw.	78.2	S	M
	Milichiidae			
	Milichiella lacteipennis (Loew)	8.6	W	O
Yauco March-Sept. 1963	Chloropidae			
	Hippelates flavipes Lw.	0.9	W	W
	H. peruanus Becker	10.4	W	O
	H. pusio Lw.	88.6	S	M
	H. tibialis Duda	0.1	W	O
Lajas March-Sept. 1963	Chloropidae			
	Hippelates apicatus Mall.	3.6	W	O
	H. currani Aldrich	0.4	W	O
	H. flavipes Loew	4.6	W	W
	H. lutzi Curran	1.7	W	O
	H. peruanus Beck.	9.6	W	O
	H. pusio Loew	68.7	S	M
	Milichiidae			
	Milichiella lacteipennis (Loew)	11.4	W	O

Locality & Sample Period	Family & Species	Relative Attraction to Baits (%)	Attraction Intensity baits	Attraction Intensity man
Parguera March-Sept. 1963	Chloropidae			
	Hippelates apicatus Mall.	5.0	W	O
	Hippelates sp. nr. *brumpti* Seguy	6.0	W	O
	H. currani Ald.	2.0	W	O
	H. pusio Loew	32.0	S	M
	Hippelates nov. sp.	8.0	W	O
	Cadrema pallida (Lw.)	9.0	W	O
	Conioscinella tripunctata (Curran)	4.0	W	O
	Conioscinella sp.	5.0	W	O
	Oscinella sp.	1.0	W	O
	Milichiidae			
	Milichiella lacteipennis (Loew)	12.0	W	O
	Sphaeroceridae			
	Leptocera sp.	16.0	W	O
Punta Arenas March-Sept. 1963	Chloropidae			
	Cadrema pallida (Lw.)	6.9	W	O
	Conioscinella sp.	6.9	W	O
	Hippelates peruanus Becker	31.1	M	O
	H. pusio Lw.	27.7	M	W
	Hippelates nov. sp.	3.4	W	O
	Chyromyidae			
	Aphaniosoma sp.	6.9	W	O
	Milichiidae			
	Milichiella lacteipennis (Loew)	4.4	W	O
	Otitidae			
	Acrosticta apicalis (Williston)	5.4	W	O
	Trixoscelididae			
	Spilochroa ornata (Johnson)	7.3	W	O
Trinidad Cocos Bay Aug. 1963	Chloropidae			
	Hippelates currani Ald.	0.6	W	O
	Hippelates sp. nr. *dorsalis* Loew	1.3	W	O
	Hippelates sp. nr. *femoralis* Duda	2.6	W	O
	H. flavipes Loew	30.6	M	W
	H. peruanus Beck.	21.2	W	O
	H. pusio Lw. variety	37.8	M	W
	Hippelates sp.	0.6	W	O
	Olcella sp.	5.3	W	O
Curepe Aug. 1963	Chloropidae			
	Conioscinella sp.	4.5	W	O
	Eugaurax quadrilineatus (Williston)	4.5	W	O
	Hippelates flavipes Lw.	32.0	M	W
	H. peruanus Beck.	41.0	M	O
	Olcella sp.	4.5	W	O
Curepe Aug. 1963	Milichiidae			
	Milichiella sp.	4.5	W	O
	Sepsidae			
	Palaeosepsis sp.	4.5	W	O
	Sphaeroceridae			
	Leptocera sp.	4.5	W	O
Brazil Rio de Janeiro Jan. 1965	Ceratopogonidae			
	Atrichopogon sp.	5.3	W	O
	Bezzia sp.	5.3	W	O
	Chloropidae			
	Conioscinella incolumis (Becker)	6.6	W	O
	Hippelates annulatus End.	11.3	W	O
	H. flaviceps (Loew)	6.3	W	O
	H. peruanus Beck.	22.0	W	O
	Oscinella sp.	7.3	W	W
	Pentanotaulax pubiseta (Becker)	7.3	W	O
	Otitidae			
	Euxesta annonae (Fab.)	23.3	W	O
	Euxesta stigmatias Lw.	5.3	W	O
Chile Puerto Varas March 1965	Chloropidae			
	Hippelates australis Sabrosky	99.0	S	M
	Sphaeroceridae			
	Leptocera sp.	1.0	W	O
Valdivia March 1965	Chloropidae			
	Hippelates australis Sabrosky	95.8	S	M
	H. nigripes Duda	4.2	W	O
Temuco March 1965	Chloropidae			
	Conioscinella inconstans (Becker)	7.5	W	O
	Hippelates australis Sabrosky	92.5	S	M
Uruguay San Jacinto Jan. March 1965	Agromyzidae			
	Genus sp. (?)	0.9	W	O
	Chloropidae			
	Conioscinella sp.	2.3	W	O
	Diplotoxa glabricollis (Thomson)	10.8	W	O
	Elachiptera sacculicornis (Enderlein)	1.9	W	O
	Hippelates parviseta (Malloch)	64.9	W	W
	H. peruanus Beck.	0.9	W	O
	Hippelates sp. nr. *annulatus* Enderlein	12.7	W	O

Locality & Sample Period	Family & Species	Relative Attraction to Baits (%)	Attraction Intensity baits	Attraction Intensity man
Uruguay San Jacinto Jan.-March 1965	Chloropidae			
	Oscinella sp.	0.9	W	O
	Dolichopodidae			
	Sympycnus nov. sp.	0.5	W	O
	Genus sp. (?)	0.5	W	O
	Milichiidae			
	Desmometopa flavicoxa Hendel	0.5	W	O
	Meoneura sp.	0.5	W	O
	Milichiella lacteipennis (Loew)	0.5	W	O
	Sciaridae			
	Bradysia sp.	0.5	W	O
	Sphaeroceridae			
	Leptocera spp.	0.9	W	O
Chuy Jan.-March 1965	Chloropidae			
	Conioscinella sp.	1.9	W	O
	Diplotoxa glabricollis (Thoms.)	22.3	W	O
	Hippelates sp. nr. *annulatus* End.	7.5	W	O
	Hippelates spp.	5.6	W	O
	Lasiopleura sp.	1.8	W	O
	Dolichopodidae			
	Genus sp. (?)	15.0	W	O
	Ephydridae			
	Genus sp. (?)	18.0	W	O
	Sphaeroceridae			
	Leptocera spp.	27.9	W	O
Peru Machu Picchu April 1965	Agromyzidae			
	Cerodontha sp.	7.3	W	O
	Anthomyzidae			
	Mumetopia nov. sp.	11.0	W	O
	Stenomicra nov. sp.	4.0	W	O
	Chloropidae			
	Conioscinella sp. nr. *pleuralis* (Becker)	11.0	W	O
	Hippelates annulatus End.	11.1	W	W
	Hippelates nov. sp. nr. *proboscideus* Will.	11.0	W	O
	Oscinella orbitalis Duda	40.6	W	W
	Oscinella sp.	4.0	W	O
Argentina Iquazu March 1965	Chloropidae			
	Conioscinella soluta (Becker)	44.0	W	O
	Hippelates peruanus Becker	52.0	W	W
	Milichiidae			
	Milichiella lacteipennis (Loew)	4.0	W	O
Costa Rica San Jose April-May 1965	Chloropidae			
	Hippelates pusio Lw.	0.4	W	W
	H. tener Coquillett	0.4	W	O
	Hippelates sp. near *dissidens* (Tucker)	69.1	W	W
	Oscinella orbitalis (Duda)	25.6	W	O
	Siphonella sp.	0.4	W	O
	Ephydridae			
	Genus sp. (?)	0.4	W	O
	Milichiidae			
	Desmometopa tarsalis Loew	0.4	W	O
	Milichiella lacteipennis (Loew)	3.3	W	O
Turrialba April-May 1965	Anthomyzidae			
	Mumetopia nov. sp. nr. *nigrimana* (Coquillett)	1.8	W	O
	Chloropidae			
	Hippelates flavipes Lw.	7.3	W	W
	Monochaetoscinella anonyma (Williston)	7.3	W	O
	Oscinella orbitalis (Duda)	61.8	W	O
	"Oscinella" rubicunda variety *costaricana* (Duda)	1.8	W	O
	Oscinella sp.	1.8	W	O
	Siphonella sp.	3.6	W	O
	Milichiidae			
	Desmometopa tarsalis Loew	1.8	W	O
	Milichiella lacteipennis (Loew)	12.8	W	O
Mexico Tuxpan May 1965	Chloropidae			
	Conioscinella spp.	21.1	W	O
	Elachiptera sp.	5.2	W	O
	Hippelates pusio Lw.	5.2	W	O
	Hippelates sp. nr. *antiguanus* Duda	21.0	W	O
	Monochaetoscinella anonyma (Williston)	10.6	W	O
	"Oscinella" rubicunda variety *costaricana* (Duda)	31.7	W	O
	Oscinella sp.	5.2	W	O
Yugoslavia Piran Oct. 1966	Chloropidae			
	Oscinella frit (L.) complex	100.0	W	O
Italy Napoli Oct. 1966	Chloropidae			
	Oscinella frit (L.) complex	100.0	W	O
Israel Tel-Aviv Nov. 1966	Chloropidae			
	Oscinella frit (L.)	100.0	W	O

Locality & Sample Period	Family & Species	Relative Attraction to Baits (%)	Attraction Intensity baits	man
Jordan Valley				
Nov. 1966	Chloropidae			
	Oscinella aharonii Duda	100.0	M	M
Kenya				
Nairobi Park (water holes)				
Nov.-Dec. 1966	Chloropidae			
	Elachiptera vulgaris (Adams)	16.7	W	O
	Oscinella sp. near *dimidiofrit* Becker	83.3	W	O
Uganda				
Kawanda (forest-grass)				
Dec.-Jan. 1966-67				
	Chloropidae			
	Conioscinella sp.	1.1	W	O
	Elachiptera scapularis (Adams)	25.6	W	O
	E. vulgaris (Adams)	45.5	W	O
	Oscinella sp. near *dimidiofrit* Becker	18.9	W	O
	Tropidoscinis nov. sp.	8.9	W	O

W = weak (less than 10 individuals collected in 12 hours.)
M = medium (between 21 and 50 individuals in 24 hours.)
S = strong (more than 50 individuals in 24 hours.)
O = no attraction established.

necessary to cling to soil particles or risk being blown away.

In Costa Rica *Hippelates* sp. near *dissidens* (Tucker) occurred in exceptionally high numbers on the dry slopes of volcanoes near San Jose. One sweep with a net in the dry grass and duff often produced over 100 individuals. This species was unattracted to man and only weakly to egg bait. Similarly, *Oscinella frit* (L.) in Europe and the Middle East, and *Oscinella* sp. near *dimidiofrit* Becker in Africa were collected in great numbers in grass and duff, but showed no attraction to man and were only very weakly attracted to rotting egg.

The West Indian and South American *Hippelates peruanus* Decker never was attracted to humans although rotting egg afforded a weak to moderate attraction for it. Sweep net samples indicated that *H. peruanus* might occur at higher densities than revealed by the bait trap samples, similar to *H. hermsi* in southern California (Mulla, 1962).

None of the species collected in eastern Peru, northeastern Costa Rica nor southern Mexico demonstrated any salient characteristics during the observation periods that would distinguish them. Most of these species apparently did not possess even a casual relationship to humans and otherwise occurred at extremely low population densities.

Considerations for Competitive Displacement and Coexistence - Preceding the introduction of any competing species, the adult habits of the candidate species must be considered. Adults must necessarily be continuously inconspicuous in the presence of man and animals. Also, the larvae must be coincident with *H. collusor*, or other target species, in identical microhabitats and abundant enough so that there would be competition between them for available food. In southern California *H. hermsi* may already fill this capacity during a major portion of the year coexisting with *H. collusor* which is the anthropophilic species.

Table 2. Species of Diptera under 4 mm long attracted to rotten egg baits in southern California.

Family and Species	Attraction Intensity baits	man
Chloropidae		
Hippelates collusor (Townsend)	S	S
H. dorsalis Loew	W	M
H. pusio Loew	M	W
H. robertsoni Sabrosky	M	M
Siphonella punctifrons Becker	W	O
Chyromyidae		
Chyromya sp.	W	O
Drosophilidae		
Drosophila busckii Coquillett	W	O
Ephydridae		
Allotrichoma sp.	W	O
Milichiidae		
Meoneura polita Sabrosky	W	O
Milichiella lacteipennis (Loew)	W	O
Milichiella sp.	W	O
Muscidae		
Fannia sp.	W	O
Hydrotaea sp.	W	O
Otitidae		
Euxesta anna Harriot	W	O
Physiphora demandata (Fab.)	W	O
Phoridae		
Megaselia spp.	W	O
Sciaridae		
Bradysia sp.	W	O
Thyreophoridae		
Omomyia regularis Curran	W	O
Trixoscelididae		
Trixoscelis frontalis (Fallen)	W	O
T. signifera Melander	W	O
Trixoscelis sp.	W	O

W = weak (less than 10 individuals collected in 12 hours.)
M = medium (between 21 and 50 individuals in 24 hours.)
S = strong (more than 50 individuals in 24 hours.)
O = no attraction established.

Among the various species of chloropids observed in the present study, several might be considered for further investigation into the possibilities for competitive displacement and/or coexistence. Of the foreign species, only *H. pusio* in Bermuda demonstrated the same degree of aggressiveness characteristic of our native *H. collusor*, *H. impressus*, (and occasionally *H. dorsalis*). Known foreign species that might best compete with *H. collusor* during periods of hot weather and which are relatively innocuous themselves are *H. annulatus*, *H. parviseta*, *H. peruanus*, and *Diplotoxa glabricollis* in South America, and strains of *Oscinella frit* in the Mediterranean area and *Oscinella* sp. near *dimidiofrit* in East Africa. Any consideration of the last two species would, however, have to take into account their potential as pests of grain in California.

Secondary considerations in which the adult gnats are moderately annoying are *H. flavipes* of the West Indies and *Oscinella aharonii* of the Middle East. *Hippelates australis* in Chile, although innocuous compared to our native pestiferous species, shows a preference for cool and wet conditions, and therefore, could potentially compete with *H. impressus* and *H. robertsoni* in California.

Other species listed in Table 1 were apparently too scarce in each respective locality to merit serious consideration for competitive displacement, or their role in competition is doubtful (e.g. Otitidae, Milichiidae, etc.).

References Cited

Bay, E.C., and E.F. Legner. 1963. The prospect for the biological control of *Hippelates collusor* (Townsend) in southern California. Proc. Calif. Mosq. Control Assoc. 31:76-79.

DeBach, P. 1964. Some ecological aspects of insect eradication. Bull. Entomol. Soc. Amer. 10(4):221-224.

1966. The competitive displacement and coexistence principles. Ann. Rev. Entomol. 11:183-212.

DeBach, P., and R.A. Sundby. 1963. Competitive displacement between ecological homologues. Hilgardia. 34(5):105-166.

Flanders, S.E. 1966. The circumstances of species replacement among parasitic Hymenoptera. Can. Entomol. 98(10):1009-1024.

Gause, G.F. 1934. The Struggle for Existence. Williams and Wilkins Co., Baltimore. 163 p.

Legner, E.F. 1967. Two exotic strains of *Spalangia drosophilae* merit consideration in biological control of *Hippelates collusor* (Diptera: Chloropidae). Ann. Entomol. Soc. Amer. 60(2): 458-462.

Legner, E.F., and E.C. Bay. 1965a. Culture of *Hippelates pusio* (Diptera: Chloropidae) in the West Indies for natural enemy exploration and some notes on behavior and distribution. Ann. Entomol. Soc. Amer. 58(4):436-440.

1965b. Predatory and parasitic agents attacking the *Hippelates pusio* complex in Puerto Rico. J. Agr. Univ. Puerto Rico. 49:377-385.

Legner, E.F., E.C. Bay, and T.H. Farr. 1966a. Parasitic and predacious agents affecting the *Hippelates pusio* complex in Jamaica and Trinidad. Can. Entomol. 98(1):28-33.

Legner, E.F., E.C. Bay and R.A. Medved. 1966b. Behavior of three native pupal parasites of *Hippelates collusor* in controlled systems. Ann. Entomol. Soc. Amer. 59(5):977-984.

Mulla, M.S. 1962. The breeding niches of *Hippelates* gnats. Ann. Entomol. Soc. Amer. 55(4):389-393.

Mulla, M.S. and R.B. March. 1959. Flight range, dispersal patterns and population density of the eye gnat, *Hippelates collusor*. Ann. Entomol. Soc. Amer. 52:641-646.

Sabrosky, C.W. 1941. The *Hippelates* flies or eye gnats; preliminary notes. Can. Entomol. 73:23-27.

1951. Nomenclature of the eye gnats (*Hippelates* spp.). Amer. J. Trop. Med. 31:257-258.

Turnbull, A.L. 1967. Population dynamics of exotic insects. Bull. Entomol. Soc. Amer. 13(4):333-337.

THE INTRODUCTION OF NATURAL ENEMIES IN CALIFORNIA FOR THE BIOLOGICAL CONTROL OF NOXIOUS FLIES AND GNATS

E.F. Legner and E.C. Bay

Department of Biological Control, University of California
Citrus Research Center and Agricultural
Experiment Station, Riverside

Pestiferous soil-breeding chloropid eye gnats and species of flies in the families Muscidae, Calliphoridae and Sarcophagidae breeding in stockpiled animal excrement have been considered as targets for biological control in California since 1962. Through 1968 the species of special concern were *Hippelates collusor* (Townsend), *H. impressus* Becker, *H. pusio* Loew, and *H. robertsoni* Sabrosky in the Chloropidae; *Musca domestica* L., *Stomoxys calcitrans* L., *Fannia canicularis* L., and *F. femoralis* Stein in the Muscidae, and *Phaenicia* and *Sarcophaga* species in the Calliphoridae and Sarcophagidae, respectively. Species of *Muscina*, *Ophyra* and *Fannia scalaris* (F.) were of limited concern.

Continuing studies begun in 1962 are to determine the biotic complexes already associated with each of these target pests in California, and to evaluate the relative importance of each constituent in the dynamics of regulation. Coincident with these domestic studies, foreign exploration for additional natural enemies of the same and related host species over a major portion of their known range in both the Eastern and Western Hemispheres has been conducted. This report documents progress of these studies and the importation program into California to the present.

Collection Methods

Natural enemies of chloropids were extracted from larval and pupal habitats by artificially exposing their developmental stages therein and by direct observation of their activity (Bay et al., 1964; Legner and Bay, 1965; Legner et al., 1966; Legner and Bay, 1964). Natural enemies of flies in stockpiled animal excrement were extracted by water-flotation and by direct egg, larval and pupal collections (Legner, 1965; Legner et al., 1967).

Discussion

Natural Enemy Species Present in California - Domestic studies have revealed the presence of a considerable array of predatory and parasitic natural enemies of these various pest species during their egg, larval, and pupal development (Bay and Legner 1963; Bay et al., 1964; Legner, 1966; Legner and Olton, 1968a; Legner et al., 1966 and 1967). High host specificity, however, appears to be restricted to parasitic species in the Coleoptera and Hymenoptera. Because their attack occurs principally against later host developmental stages, their effects on population regulation of the hosts is theoretically greater than egg and larval predators, so that their candidacy as biological control agents is emphasized (Legner and Olton, 1968).

Colonized Natural Enemies - Tables 1 and 2 list those natural enemy species that have been colonized in California for the biological control of *Hippelates* eye gnats and dung-breeding flies, respectively. Appropriate literature references and the University of California Department of Biological Control pertinent importation S. & R. Report number are included for the benefit of future references.

Distinguishing Characteristics of Imported Natural Enemies - For biological control of eye gnats, the cynipid, *Hexacola* sp. near *websteri* (Crawford), secured in hot and dry areas of the West Indies, attacks young *Hippelates* larvae in recently wet (irrigated) field. Its parasitization rate under these West Indies conditions has been considerably greater than our native *Hexacola* sp. from similar habitats (Legner and Bay, 1964).

The diapriid pupal parasite, *Trichopria* sp., was similarly more active in the West Indies than our native *Trichopria (=Phaenopria) occidentalis* (Fouts) (Legner and Bay, 1964; Legner et al., 1966).

Two West Indian strains of the pteromalid, *Spalangia drosophilae* Ashmead, exhibiting various unique characteristics of fecundity and longevity (Legner, 1967), were favored as candidates for introduction.

Some native Californian parasites were translocated to portions of the state where they were not known to occur, in order to increase local natural enemy complexes (Table 1).

The activity of native and imported natural enemies is largely curtailed when the fields in which their hosts are located are cultivated (Legner, 1968). This is seemingly a result of burying already-formed puparia out of reach of their enemies as previously hypothesized (Bay and Legner, 1963), and through the breaking of the habitat attraction stimuli for both larval and pupal parasites (Legner, 1968; Legner and Olton, 1969).

For biological control of flies breeding in animal excrement, the encyrtid *Tachinaephagus zealandicus* Ashmead has been found especially active under a wide array of climatic conditions in field and stockpiled excrement in the Southern Hemisphere (Legner et al., 1967; Legner and Olton, 1968a), where it parasitized larvae of several fly species.

Table 1. Natural enemies of *Hippelates* eye gnats colonized in California through 1968.

Family and Species	Type[1]	Origin and S&R Report No.	Number released	Dates colonized	References
Cynipidae					
Hexacola sp. near *websteri* (Crawford)	LS	Puerto Rico S&R 63-58	56,800	1964-68	Legner & Bay (1964, 1965)
Diapriidae					
Trichopria occidentalis (Fouts)[2]	PuEn	S. California	8,000	1962-65	Bay & Legner (1963) Bay et al. (1964)
Trichopria n. sp. (?)	PuEn	Jamaica S&R 63-39	47,272	1964-68	Legner et al. (1966)
Pteromalidae					
Eupteromalus hemipterus (Walker)[2]	PuS	S. California	61,425	1962-68	Bay et al. (1964)
Spalangia drosophilae Ashmead[2]	PuS	S. California	28,000	1962-68	Bay & Legner (1963) Bay et al. (1964)
Spalangia drosophilae Ashmead	PuS	Jamaica S&R 63-40	55,590	1964-68	Legner et al. (1966)
Spalangia drosophilae Ashmead	PuS	Puerto Rico S&R 63-29	13,010	1964-68	Legner & Bay (1965)
Staphylinidae					
Aleochara n. sp. (?)[2]	PuS	S. California	8,100	1966-67	–

[1]LS = larval, endophagous, solitary; PuS = pupal, ectophagous, solitary; PuEn = pupal, endophagous, solitary.

[2]Native species disseminated in areas where they were not known to occur.

Table 2. Natural enemies colonized in California through 1968 on species on Muscidae, Calliphoridae, and Sarcophagidae breeding in stockpiled animal excrement.

Family and Species	Type[1]	Origin and S&R Report No.	Number released	Dates colonized	References
Encyrtidae					
Tachinaephagus zealandicus Ashmead	LG	Australia – New Zealand S&R 67-36-14	38,885	1967-68	Legner & Olton (1968a, b) Legner et al. (1967)
Pteromalidae					
Muscidifurax raptor Girault and Sanders	PuSu	Puerto Rico S&R 63-51	241,980	1964-68	Legner (1965 & 1969)
M. raptor G. & S.	PuG	Chile S&R 65-29	18,045	1965-68	Legner et al. (1967) Legner (1969)
M. raptor G. & S.	PuS	Costa Rica S&R 65-40B	10,500	1966-68	Legner (1969) Legner et al. (1967)
Spalangia cameroni Perkins[2]	PuS	Trinidad, W.I. S&R 63-46	79,670	1964	Legner et al. (1967)
S. cameroni Perkins	PuS	Australia S&R 67-36	1,500	1968	Legner & Olton (1968)
S. cameroni Perkins	PuS	Jamaica S&R 64-20	13,900	1964	Legner et al. (1967)
Spalangia endius Walker[2]	PuS	Puerto Rico S&R 63-31	122,185	1964	Legner et al. (1967)
S. endius Walker	PuS	American Samoa S&R 67-83	1,680	1968	Legner & Olton (1968)
Spalangia longepetiolata Boucek	PuS	Kenya-Uganda S&R 66-53C	3,575	1967-68	Legner & Olton (1968) Legner and Greathead (1969)
Spalangia nigra Latreille[3]	PuS	N. California	950	1967-68	– –
Spalangia nigroaenea Curtis[2]	PuS	Wisconsin S&R 63-65	79,690	1964	Legner et al. (1967)
Sphegigaster sp.	PuS	South Africa S&R 67-8/6	685	1967-68	Legner & Olton (1968)
Staphylinidae					
Aleochara taeniata Erichson	PuS	Jamaica S&R 64-8	201	1964-65	White & Legner (1966)

[1]LG = larval, endophagous, gregarious; PuG = pupal, ectophagous, gregarious; PuS = pupal, ectophagous, solitary, and uniparental.

[2]Strain already present in California.

[3]Native species disseminated in areas where they were not known to occur.

The larvae of most of our pestiferous fly species in California were free from effective parasitization (Legner, 1966, and unpublished data). *Tachinaephagus zealandicus* has now been recovered in California from *Musca* and *Fannia* species in stockpiled excrement and from *Sarcophaga* spp. in carrion. Parasitization of the latter hosts often exceeds 95%.

Three separate reproductively isolated forms of the pteromalid, *Muscidifurax raptor* Girault and Sanders, have been introduced to complement our two native forms (Legner and Olton, 1968a and 1968b). The imported forms differ in that one is gregarious in larval development, another is uniparental and the third is merely isolated reproductively (Legner, 1969).

Spalangia longepetiolata Boucek, a pteromalid pupal parasite from East Africa, demonstrated great parasitization activity at cool high elevations, and especially in poultry excrement. It is expected that this species will be a valuable addition to the parasitic fauna in coastal California where cool weather conditions prevail, and hopefully during the winter on *Fannia femoralis*.

Sphegigaster sp., another pteromalid pupal parasite from Africa, was found to favor host puparia near or at the surface of the habitat, making it suitable for certain conditions of *Fannia* pupation.

Aleochara taeniata Erichson, a staphylinid parasite-predator from drier regions in the West Indies (White and Legner, 1966) was added to the Southern California natural enemy complex in the hope that it may supplement local *Aleochara* species that rarely assume any dominance during the summer months.

Various exotic strains of *Spalangia* species were also introduced for the purpose of increasing their effective climatic range (Table 2).

Additional Candidates for Biological Control - We will issue a report shortly on the distribution of wholly predatory and scavenger species found in stockpiled animal excrement in various major portions of the globe. The main theme will attempt to show that although there are indeed a number of cosmopolitan predatory and scavenger species, there are also many localized non-cosmopolitan species that might be considered as candidates for introduction. The greatest differences seem to exist between the Holarctic and the Ethiopian and Neotropical regions. Representative fly breeding sites have now been investigated in all of the world's domestic fly regions except for parts of Asia. Of those regions visited northern Europe, South America, and western Africa have been the least well explored and it is here that it is felt additional parasites of those hosts may yet be found.

Considering the close similarity of parasite types and behaviors that have already been found to be distributed widely over the globe, and the frequency with which the same group (i.e. *Spalangia* sp.) recurs dominant it seems unlikely that we will yet discover species that are substantially different or more promising than those which we now have. More adaptive strains of these species for selected localized habitats is perhaps the most that we can anticipate. This does not, however, preclude the possibility that such natural enemies may exist which have been overlooked due to their strong density dependence, and consequently their extreme scarcity where the host is under their specific control. This possibility tantalizes us particularly in those situations where conditions appear ideal for muscoid fly breeding, but where flies are unaccountably fewer than we are accustomed to associate with the best natural enemy activity that we know.

Similarly for *Hippelates* species, apart from the existence of different strains of the West Indian parasites in other portions of the Neotropics (authors' unpublished data), we believe that a major portion of the note-worthy parasitic fauna has been discovered. It is doubtful that other superior species will be forthcoming. Wholly predatory fauna in the *Hippelates* microhabitat is consistently of such extremely low density that it is unlikely that such fauna plays a vital role in the regulation of *Hippelates* populations.

References Cited

Bay, E.C., and E.F. Legner. 1963. The prospect for the biological control of *Hippelates collusor* (Townsend) in southern California. Proc. Calif. Mosq. Control Assoc. 31:76-79.

Bay, E.C., E.F. Legner, and R. Medved. 1964. *Hippelates collusor* (Diptera: Chloropidae) as a host for four species of parasitic Hymenoptera in southern California. Ann. Entomol. Soc. Amer. 57(5):582-584.

Legner, E.F. 1965. Un complejo de los artropodos que influyen en los estadios juveniles de *Musca domestica* L. en Puerto Rico. Carib. J. Sci. 5(3-4):109-115.

1966. Parasites of the house fly and other filth-breeding Diptera in southern California. J. Econ. Entomol. 59(4):999-1001.

1967. Two exotic strains of *Spalangia drosophilae* merit consideration in biological control of *Hippelates collusor* (Diptera: Chloropidae). Ann. Entomol. Soc. Amer. 60(2):458-462.

1968. Parasite activity related to ovipositional responses in *Hippelates collusor*. J. Econ. Entomol. 61(5):1160-1163.

1969. Reproductive isolation and size variation in the *Muscidifurax raptor* Girault and Sanders complex. Ann. Entomol. Soc. Amer. 62(2):382-385.

Legner, E.F., and E.C. Bay. 1964. Natural exposure of *Hippelates* eye gnats to field parasitization and the discovery of one pupal and two larval parasites. Ann. Entomol. Soc. Amer. 57(6):767-769.

1965. Predatory and parasitic agents attacking the *Hippelates pusio* complex in Puerto Rico. J. Agr. Univ. Puerto Rico. 49(3):377-385.

Legner, E.F., and G.S. Olton. 1968a. Activity of parasites from Diptera: *Musca domestica, Stomoxys calcitrans*, and species of *Fannia, Muscina*, and *Ophyra*. II. At sites in the Eastern Hemisphere and Pacific area. Ann. Entomol. Soc. Amer. 61 (5):1306-1314.

1968b. The biological method and integrated control of house and stable flies in California. Calif. Agr. 22(6):1-4.

1969. Migrations of *Hippelates collusor* larvae from moisture and trophic stimuli and their encounter by *Hexacola* parasites. Ann. Entomol. Soc. Amer. 62(1):136-141.

Legner, E.F., E.C. Bay, and T.H. Farr. 1966. Parasitic and predacious agents affecting the *Hippelates pusio* complex in Jamacia and Trinidad. Can. Entomol. 98(1):28-33.

Legner, E.F., E.C. Bay, and E.B. White. 1967. Activity of parasites from Diptera: *Musca domestica, Stomoxys calcitrans, Fannia canicularis*, and *F. femoralis*, at sites in the Western Hemisphere. Ann. Entomol. Soc. Amer. 60(2):462-468.

Legner, E.F., E.C. Bay, H.W. Brydon, and C.W. McCoy. 1966. Research with parasites for biological control of house flies in southern California. Calif. Agr. 20(4):10-12.

Legner, E.F., and D.J. Greathead. 1969. Parasitism of pupae in East African populations of *Musca domestica* L. and *Stomoxys calcitrans* (L.). Ann. Entomol. Soc. Amer. 62(1):128-133.

White, E.B., and E.F. Legner. 1966. Notes on the life history of *Aleochara taeniata*, a staphylinid parasite of the house fly, *Musca domestica*. Ann. Entomol. Soc. Amer. 59(3):573-577.

COLLECTING ADULT TABANIDS USING A "STICKEM" TRAP BAITED WITH CARBON DIOXIDE[1]

A. Bruce Knudsen and Don M. Rees

Center for Environmental Biology
University of Utah, Salt Lake City

[1]This study is supported in part by funds provided by Research Grant No. 12-14-100-8070(33), Agricultural Research Service, Entomology Research Division, United States Department of Agriculture.

Knudsen and Rees (1968) described and briefly evaluated the following methods used in this study to collect Tabanidae in Utah: a drying chamber for obtaining tabanid larvae, and insect nets, emergence traps, Malaise traps and "Stickem Special" traps for collecting adults. The most productive method used for collecting adults was the "Stickem Special" trap constructed with 2 twelve-inch-square surfaces to which a slow-drying adhesive substance, "Stickem Special," (Michell and Pelton Company, Emeryville, California) was applied.

In the summer of 1968 a modified "Stickem" trap with 4 twelve-inch-square surfaces was constructed. In an attempt to increase the number of flies coming to the trap, CO_2, as dry ice, was used as an added attractant (Figure 1). The carbon dioxide baited trap was used at one site only. At five other sites in the study area, 10 four-sided, nonbaited "Stickem" traps were operated. The traps were placed in a vertical position with the bottom of each side twelve inches above the ground with the four surfaces of the trap facing north, south, east and west.

During the 1968 season the ten nonbaited "Stickem" traps with two traps in each location were placed, when possible, one in greasewood, *Sarcobatus vermiculatus* (Hook) Torr., and the other in saltgrass, *Distichlis stricta* (Torr.) Rybd. This was done in an attempt to determine whether differences exist in the number of flies present in the two vegetative types.

The traps were operated continuously from June 12 to November 1, 1968. The trapped flies were counted, identified and removed three times a week at about 48-hour intervals.

Results

During this 4½ month period, 46,311 adult female flies were collected on the ten nonbaited traps. Six tabanid species were collected, namely: *Chrysops discalis* Williston, *Chrysops aestuans* van der Wulp, *Hybomitra sonomensis* Osten Sacken, *Tabanus productus* Hine, *Tabanus similis* Macq., and *Atyletus incisuralis* (Wlk.).

"Stickem" Trap With Carbon Dioxide - The CO_2 baited trap was operated in greasewood. A dry ice chamber was constructed of styrofoam, two inches thick and fourteen inches square on the outside. This chamber was placed on the ground within the four inside surfaces of a "Stickem" trap. Dry ice was placed in the chamber and a one-inch-square hole was cut near the top of each side of the chamber to provide for the release of the CO_2 attractant. The amount of dry ice used during a day ranged from five to ten pounds, depending on the temperature.

Adult female tabanids that were attracted swarmed about the trap and would generally alight on the sticky surface where they became attached. The "Stickem" material was applied to a depth of approximately one-eighth of an inch at the beginning of each day when collections were made.

The collections were made once or twice a week from July 3 to September 24, 1968. The collection period was 2½ hours. From one to six collections were made each day the trap was operated with an average of three periods per day. During the last half hour of each period, the flies were identified, counted, and removed from the trap with forceps. At times, due to the great number of flies captured, counting and removal required an hour or more. The counting of a single twelve-inch-square surface became difficult when the flies became attached in superimposed sticky layers. The counting was further hampered by the large, bee-like swarms of tabanid females which constantly circled the trap while this work was in progress.

The number of flies on the four surfaces was tabulated separately and divided into two time periods per day in order to determine possible effects of temperature and light on the collections made on each side of the trap. Time Period I included those flies collected from 7:45 a.m. to 1:30 p.m., the approximate meridian due to daylight savings time. Period II included flies collected from 1:30 to 9:00 p.m. Data recorded during each sampling period included temperatures and time of day. Following each count, the subsequent 2½ hour period began. This procedure was generally followed throughout the day.

Results

During the season, 40,332 adult female tabanids were collected in the CO_2 baited trap during 115 hours (46 2½-hour periods) conducted on seventeen days. Very few male tabanids were captured. An average of 350.71 flies were collected per hour, or 876.8 flies per 2½-hour period. The number of flies counted for a single 2½-hour period ranged from zero to 3,400. By comparison during a period of 76 days, July 3 to September 26, the greatest number of tabanids collected in a single non-baited "Stickem" trap operated in greasewood was 6,541. This trap was operated continuously on an average of thirteen daylight hours per day. The hourly average was 6.62 flies. The number of flies counted over a 48-hour period, 26 daylight hours, ranged from zero to 1,226 (Figure 2).

The temperature at which the CO_2 baited collections were conducted ranged from 54° to 95°F. Five tabanid species were collected; they are, in order of their abundance: *C. discalis* (39,658); *H. sonomensis* (668); *T. productus* (4); *T. similis* (1); and *Chrysops fulvaster* O.S. (1) Figure 3.

The number of flies counted on each baited trap surface during the season was: north (11,675); east (12,691); south (6,454); and west (9,512). A comparison of the percent of flies collected on the four surfaces during the two time periods is: Period I, north (33.1%); west (30.1%); east (22.5%); and south (14.2%). Period II, east (38.9%); north (25.8%); west (17.9%); and south (17.4%). The highest percent of flies collected was on the shaded surfaces of the trap. The reason for this apparent preference is not known but may be due to either differences in temperature or light intensity.

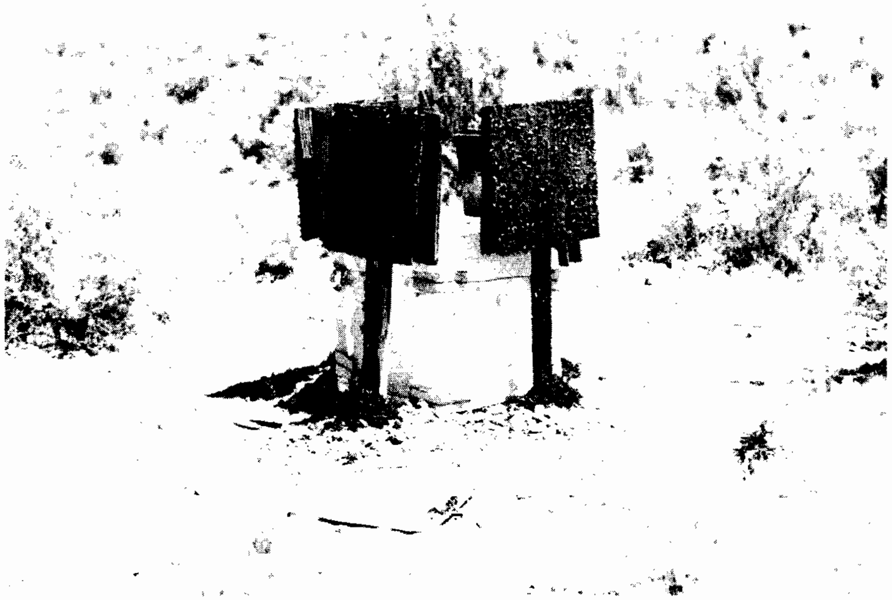


Figure 1. "Stickem" Trap baited with CO_2.

FIGURE 2. 1968 SEASON

NUMBER OF ADULT TABANIDS COLLECTED IN BAITED AND NON-BAITED "STICKEM" TRAP.

TRAP TYPE	COLLECTION PERIOD	NO. COLL.
ONE, CO_2 BAITED TRAP	2 1/2 MOS. (17 DAYS)	40,332
TEN, NON-BAITED TRAPS	4 1/2 MOS. (CONTINUOUS OPERATION)	46,311
	TOTALS:	86,643

SINGLE TRAP COLLECTIONS

TRAP TYPE	COLLECTION PERIOD	NO. COLL.	AVE./HR.	MAX. NO./PERIOD
BAITED	2 1/2 MOS. (17 DAYS, 115 HRS)	40,332	350.71	3,400 (2 1/2 HRS)
NON-BAIT.	2 1/2 MOS. (76 DAYS, 988 HRS)	6,541	6.62	1,226 (26 HRS.)

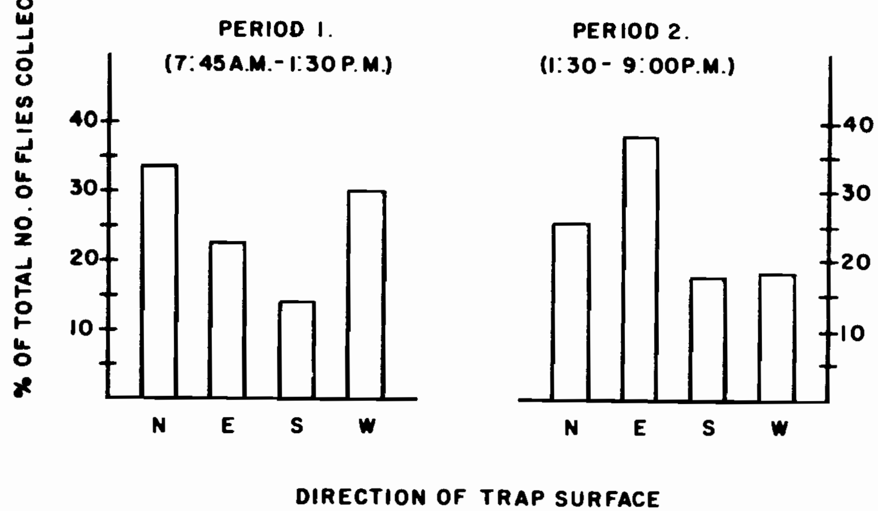
FIGURE 3. 1968 SEASON

TOTAL NO. OF ADULT TABANIDS COLLECTED, BY SPECIES USING A CO_2 BAITED "STICKEM" TRAP.

SPECIES:	NO.	PERCENT
CHRYSOPS DISCALIS WILL.	39,658	98.3
HYBOMITRA SONOMENSIS O.S.	668	1.7
TABANUS PRODUCTUS HINE	4	-
T. SIMILIS MACG.	1	-
C. FULVASTER O.S.	1	-
TOTALS:	40,332	100%

FIGURE 4. 1968 SEASON

COMPARISON OF ADULT TABANID NUMBERS COLLECTED DURING TWO DAYLIGHT PERIODS USING A CO_2 BAITED "STICKEM" TRAP.



Conclusions

1. During this study a CO_2 baited "Stickem" trap collected fifty-three times the number of flies taken in any nonbaited "Stickem" trap. This was determined on an average day light hourly basis of trap operation.

2. No significant differences were apparent in the number of tabanids collected in the nonbaited traps operated in greasewood and saltgrass vegetation.

3. On the CO_2 baited trap the shaded surfaces were more attractive to the flies than the nonshaded surfaces.

4. As a result of this study it can be assumed that "Stickem" traps baited with CO_2 have a potential use for the control of tabanids. Larger traps, in greater numbers, in selected areas, may substantially reduce tabanid populations. The cost of larger scale operation of such traps for control purposes may prohibit their use.

References Cited

Knudsen, A. Bruce, and Don M. Rees, 1968. Methods used in Utah to sample tabanid populations. Mosq. News. 28(3):356-361.

MIDGE CONTROL IN FLOOD CHANNELS

Curtis L. Barnes

Orange County Mosquito Abatement District

We in Orange County have major problems other than mosquitoes in our flood control channels, as well as in the depressions, water spreading areas and reservoirs. This problem is the production of excessive numbers of chironomid midges. Our District entomologist, John G. Shanafelt, has identified our chironomids as belonging to the following genera: *Chironomus*, *Tanypus*, *Procladius* and *Goeldichironomus*.

It is interesting to note that this problem has gradually increased over the past ten years. Factors which have brought about this change include the construction of new flood channels, water spreading operations, reservoirs and ornamental lakes as well as the human population boom. With the steady influx of people, agricultural areas were replaced by urban developments. New flood channels were dug to provide street drainage required by the new subdivisions. In 1957, we listed 36 flood channels, totaling 70 miles in length. As a comparison, today we list 107 channels, 238 miles in length, a 200% increase in about 10 years.

As new channels were put in operation, the treatment of mosquito breeding began and the mosquito population was kept to a minimum, or at 100% control. These areas were treated on a 10 to 18 day cycle with 1% ABATE® or Baytex® granules. In 1966-67, the midge population in flood channels began to develop, running from an average of 8 to 150 larvae per square foot, with the starring role of *Chironomus* and *Tanypus* leading the credits. By the end of 1967, the midge population was on a great upswing lasting through the winter months. The midge problem was getting to a critical stage as homes were being built next to the channels. Adult midge populations resting on the walls and windows of these homes reached as high as 2,000 per side. At the beginning of 1968, we began a study of the midge production in one of these channels three miles in length. The primary purpose was to determine better control methods to reduce or minimize the midge production and to determine the species. Various factors were evaluated. Much depended upon the ecology and the habits of the particular species to be controlled. A valid choice of larvicide depended on an entomological determination of the species present. To date, we have found that climatic conditions have played no major role in these area.

For our inspections and control, we selected a channel three miles in length and 50 feet wide. Inspections were made every seven days and treatments on a 7 - 14 day cycle. We are not presenting a complete record, only one in content as to highlights of this channel.

Table 1. Results of midge investigation and treatment in an Orange County flood control channel, 1968.

Test No.	Larvicide	Formulation	Application Rate Lbs/acre	Midge Larvae/Sq. Ft. Pre-Treatment	Midge Larvae/Sq. Ft. Post-Treatment	% Reduction
1	Baytex	2% granules	0.20	50	50	0
2	ABATE	1% granules	0.20	100	100	0
3	Ethyl parathion	2% granules	0.20	150	150	0
4	Methyl parathion	2% granules	0.20)			
		2% granules	0.20)	150	25	83%
		2% granules	0.20)			
		2% granules	0.20)			
5	Methyl parathion	4% granules	0.20	200	100	50%
6	Carbamate*	4% granules	0.04	100	50	50%

*Experimental granules furnished by Dr. Mir Mulla of the University of California, Riverside. Post-inspection 72 hours after treatment.

The evaluation of the chart was concluded in this manner: even though Baytex and ABATE have been used successfully in the past two seasons on roadside ditches, gutters and catch basins for the treatment of mosquitoes, the two insecticides performed at a low level in the channel for the control of midges. Methyl parathion and the experimental carbamate appear to be the best insecticides for the control of chironomid midge problems in Orange County at this time.

From an operational standpoint we have found by experience that when larval counts reach an average of 10-50 per square foot, a public nuisance is created which affects the homes bordering the flood channels. The number of adult midges observed resting on the sides of the homes will be several hundred. As the larval counts increase, the nuisance becomes intense and the adult midges move farther away from the channel. Homes located three blocks away have been affected when larval counts reach 100-200 per square foot. When these larval counts are reached, the rate of adult emergence is so great that a nuisance is created in the following manner:

1. Adult midges from 50 to several thousand can be found around protected areas of the home. Due to the homes being so close to the channels, the midges are attracted to the homes by lights at night.

2. Adult midges readily enter the house or create a mental agony to the housewife when they drop into and onto food and food containers.

3. Due to large numbers around the homes, two physical hardships are brought about.

    a. When homes are being constructed, a problem is created for the painters, as adults light upon newly painted surfaces and in some instances re-painting must be done. This situation also arises when the homeowner is re-modeling the home.

    b. Due to the large number of adults, another condition arises, this being the adults laying eggs on the sides of homes. Each mass contains 1 to 2000 eggs and at times the sides of the homes are discolored and must be re-painted even though the homes are only one to two years old.

4. A distinct disadvantage to the District is created by the likeness of the adult midges to mosquitoes. This holds true for about 95% of the general public. Due to this, much time and effort is spent on service requests and educating the public as to the difference between the two insects.

DURSBAN® EFFECTIVE FOR MOSQUITO CONTROL IN CREEK BOTTOMS AND DUCK PONDS

Dale W. Best

Orange County Mosquito Abatement District, Santa Ana

A field experiment to determine the ability of Dursban® to disburse through thick vegetation and provide larval control in sewage effleunt discharged into a dry creek bed two miles long was set up in September of 1967.

The quantity of Dursban to be applied was determined by the district entomologist, John G. Shanafelt, on the basis of flow in gallons per minute to give an application rate of 0.4 ppm over a one hour period.

With the formation of Rossmoor Leisure World Sub-Division, plans were to use the waste water from the sanitation plant on the golf course. The water is held in a reservoir and then pumped out for irrigation; but due to the increase in population, excess treated effluent was discharged into San Diego Creek in accordance with requirements established by the Santa Ana River Regional Water Control Board. Rates as high as 800,000 gallons per day were observed. This creek is grown up with cattails, willows and weeds and is inaccessible to spray by hand or by power equipment.

Pre-treatment inspection showed larval counts of *Culex peus* at 250 per dip. Egg rafts were also present. On September 12, 1967, 0.125 lb of Dursban in six gallons of water was introudced through spraying systems T Jet Nozzle 8001 over a period of one hour at the point of discharge into San Diego Creek. After 24 hours 100% mortality was observed for 5,000 feet downstream from the point of application. 90% mortality was observed for the next 5,000 feet to the point where the stream was dammed off. After 48 hours no mosquito larvae could be found. Pupae were taken at the rate of only one in 25 dips. Mosquito fish were not affected.

The rate of application, based on the actual area of affected kill, was 0.05 lb per acre. The total area was approximately 2.5 acres.

Reinfestation did not occur for 28 days after treatment when first instar *Culex* larvae were observed. Sixty days after treatment a second application of 0.125 lb of Dursban was injected over a one hour period. *Culex peus* were present in all stages at the rate of 2-3 per dip. Mosquito fish were present but could not establish complete control because of the dense vegetation. 100% mortality was obtained after 48 hours and reinfestation was not observed until 25 days later when first to third instars were taken at the rate of three per dip in isolated places.

In August of 1968 this section of San Diego Creek was treated the same way as in 1967. Pre-treatment inspection found *Culex peus* larvae at 500 per dip. Dursban was applied to the flowing water to give a 0.6 ppm dosage rate or an equivalent rate of 0.08 pounds per acre. Control after 24 hours was 100%. Dead chironomid larvae were observed. Mosquito fish were not affected. The next treatment was not required until 39 days later.

In duck club operation it is always desirable to start early flooding of duck ponds to attract ducks. In Orange County this flooding is started in late August or early September. This is always about 40 days before duck season opens in October. The San Joaquin Duck Club started flooding ponds in late August, 1968. First *Culex* larvae started showing up the first part of September.

Mosquito control in ponds that are flooded by duck clubs is the responsibility of the duck club owners. Except in an emergency the spraying is done by club employees with the help of district inspection.

With the cooperation of the duck club owners, certain ponds were picked out for field experimental use of Dursban. Spraying was done by the District using two gallon hand sprayer and 8001 T Jet Nozzle.

Four ponds with a total area of 10.5 acres were sprayed at the rate of 0.05 lb Dursban per acre. Pre-treatment inspection showed larval and pupal counts from 100 to 250 per dip. A twenty-four hour check showed counts of 10 to 75 per dip but after 72 hours 100% mortality was obtained. Post-treatment inspection for 30 days showed hardly any buildup.

USE OF FLIT® MLO FOR URBAN MOSQUITO CONTROL

Nicholas D. Perruzzi

Orange County Mosquito Abatement District, Santa Ana

Flit® MLO was successfully used during the 1968 season to control mosquito breeding within 10 square miles of urban area.

Flit MLO is a larvicidal oil developed by the Humble Oil and Refining Company. This new insecticide was first investigated by company research scientists in 1962. Laboratory work was started in 1963 and extensive field testing was done in early 1967 at selected locations in Texas, Louisiana and Mississippi. These tests were conducted in drainage ditches, catch basins and salt marches.

Our District began using Flit MLO on a community drainage route on July 11, 1968. The testing was done in the cities of Placentia and Yorba Linda, located in northern Orange County. The Flit MLO was applied by the control operator on a routine operational basis within the 10 square mile test area. Similar breeding sources in other urban areas under the jurisdiction of the control operator, consisting of 22 square miles, were treated with Baytex® granules and/or Baytex oil solution. The effectiveness of Flit MLO in controlling mosquito breeding within the test area was compared with the effectiveness of the District's standard procedures described above. The total urban area within the District is 310 square miles.

The number of days between tests was 13.3 days. The amount of Flit MLO used was 133 gallons. For off-street application, Flit MLO was applied by two-gallon hand can using 40 psi and a Spraying System No. 8001 nozzle. For all other treatment, the MLO was applied from a jeep driven at approximately 5 mph, using the same nozzle and pressure.

Records were kept during the testing listing all 25 test sources. Where breeding was found, it was recorded showing stage and amount per dip. For simplicity, the number of larvae per dip were indicated in their degree of intensity as follows: Light 0 to 10; Medium 10 to 50; and Heavy 50+. Test sites that were found breeding were treated at the rate of four gallons per acre.

After treating test sites with Flit MLO, the first check was made after a time lapse of 24 hours. A second check was made after a time lapse of 48 hours. After testing for a five-month period, the following observations were made: Flit MLO is easily applied using a fan-spray pattern except on a reasonably windy day. Where there is a heavy growth of weeds or grass, the time needed for treatment increases because of the difficulty in getting Flit MLO through the growth onto water. This would also be true for any oil solution. It was observed that where water was covered with a foreign substance, there was a problem getting Flit MLO to cover the surface.

On the 24-hour check, it was found that 90% mortality was achieved on larvae of all stages and 75% mortality on pupae. The 48-hour check, however, revealed that 95-100% mortaltiy was achieved on all stages of larvae and on pupae. From an operational standpoint, the use of Flit MLO on a two-week spray cycle gave satisfactory control of mosquito breeding in community drainage facilities within urban areas. A seven-day spray cycle was required in the other urban areas of Orange County using standard larvicides during this test period. The use of Flit MLO in the 10 square mile test area reduced by 50% the man hours normally required for spraying the community drainage sources.

INTERAGENCY DEVELOPMENT OF PEST CONTROL BULLETINS

Frank W. Pelsue

Southeast Mosquito Abatement District, South Gate

The history of pest control bulletins dates back many years. Many agencies have developed various types of bulletins, independently, to disseminate information regarding the control, description, and biology of various pest species. Bulletins and circulars published by the USDA are usually intended for use by technical personnel or people working in the field of pest control, with a few geared to the layman. This is also true of material published by the State Departments of Public Health and Agriculture, as well as universities.

Pest bulletins and circulars intended for the layman are usually distributed, upon request, by the University of California Agricultural Extension Service, through the local farm advisor's office, agricultural commissioner's office, state and county public health departments, and mosquito abatement districts. These one or two page pest bulletins are made up independently by the various agencies and usually pertain to pests most commonly encountered by the layman, such as: fleas, flies, clover mites, fungus gnats, cockroaches, and spiders. Each agency usually only has pest bulletins that cover pests pertinent to that agency, for example, the county health department only has bulletins for general distribution on public health pests, but they get requests for information regarding agricultural pests and garden pests. When the health department receives a call regarding an agricultural pest control problem, the entomologist can either give the necessary information for control of the pest verbally over the telephone if he is familiar with the control of this particular pest, or he can refer the inquiring person to the farm advisor or the agricultural commissioner.

The idea of cooperative development of pest control bulletins is not new. Orange County has developed a series of pest control bulletins, utilizing several cooperating agencies including the Orange County MAD. In Los Angeles County, the following agencies are cooperating in the development of a series of pest control bulletins and include: Southeast MAD, Los Angeles County Health Department, Los Angeles County Agricultural Commissioner's Office, Farm Advisor's Office, and the State and County Arboretum. Under the leadership of the Manager of the Southeast MAD, Gardner C. McFarland, a committee was formed with one member representing each agency. The Agricultural Commissioner's Office was appointed chairman of the committee and editor of the bulletins. The committee was given official recognition by the Board of Supervisors of Los Angeles County, and it was decided that one agency would budget for the cost of publication. In our case, the agricultural commissioner will budget to cover costs; however, it makes no difference what agency does the budgeting, but it is more feasible if only one agency does the budgeting.

Probably the primary purpose for having an inter-agency pest control bulletin is to provide uniform standardized information geared to the layman, enabling him to cope with the common pest control problems that are encountered in or about the home. Each agency is disseminating the same information, thus eliminating the possiblity of confusion that might arise when recommending a particular control measure. Another minor reason for having an inter-agency pest control bulletin is that the workload is spread around enabling more pests to be covered in a shorter period of developmental time. Public relations is an important factor in using an inter-agency pest control bulletin, in that it eliminates switching a person from one agency to another which sometimes upsets people inquiring about control measures over the phone. These also provide a ready reference.

The pest bulletin consists of a single sheet with a heading, "Pest Control Bulletin" in bold letters. Just above the heading in smaller letters is County of Los Angeles inter-agency to denote that it is a cooperative effort with no reference to a particular agency. The name of each agency distributing the bulletins is stamped on by that particular agency listing the name, address, and telephone number. The bulletins are also numbered consecutively. The bulletin contains a brief description of the pest, its general habits, and practical control measures. The chemicals mentioned in the control section of the bulletin are only those which have the pest being discussed on the label. We attempt to stress to the people using these bulletins the importance of following the directions on the label of the pesticide, so we have our "cautions" section outlined in large bold lines so this section can be readily seen. This relieves the agency of any responsibility if the pesticide is misused. At the present time, there are 13 bulletins available covering the following pests:

Current Pest Control Bulletins

1. Clover Mite
2. Ants
3. False Chinch Bug
4. Fleas
5. Honey Bees
6. March Flies
7. Spiders
8. Fungus Gnats
9. Wasps
10. Silverfish and Firebrats
11. Termites
12. Food Infesting Insects
13. Cockroaches

Some of the pests to be covered in succeeding bulletins are flies, wood boring beetles, carpet beetles and clothes moths, bed bugs, box elder bugs, earwigs, crickets, ground beetles, chironomid midges, mosquitoes, and ticks.

We believe that these bulletins are an aid to the public, and they are certainly an aid to the agencies which distribute them. We hope this might stimulate more counties to develop similar types of inter-agency pest control bulletins.

GENERAL OPERATIONAL PROGRAM IN THE DELTA MOSQUITO ABATEMENT DISTRICT

Robert E. Turner

Delta Mosquito Abatement District, Visalia

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 were to make an effective program impossible unless the District were 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 ground 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 nigromaculis*), 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 premises by premises 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 week 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.

FRESNO WESTSIDE MOSQUITO ABATEMENT DISTRICT EVALUATION ZONES TO EQUALIZE WORKLOAD

Chester E. Owens

Fresno Westside Mosquito Abatement District, Firebaugh

The information for this project was drawn from the operators' daily control reports and is based on a standard of controlling mosquitoes to below the nuisance level.

This evaluation was designed to equalize the workloads of the zone operators and to reassure the administrative staff concerning observations and vocal communications. It can also be used as a guide for future evaluations, but it should be remembered that this evaluation is not entirely valid. There are certain human factors that will influence the evaluation that will not be brought out; such as, one operator is more capable of being better organized, both physically and mentally to perform his duties.

This study is not intended to evaluate the operator but to evaluate the zone. Since one cannot dismiss the fact that the innate abilities of each operator will have an effect upon the figures that appear in the summary, good field supervision must be supplied to remedy the weaknesses of the system.

Table 1. Monthly summaries of Zone 1 control reports.

Months	Acres Treated Aircraft	Time in Hours				Use of Ground Equipment				
		Insp.	Spray	General	Shop	No. of Stops	Gallons Sprayed	Acres Treated	Sq. Ft. Treated	Mileage
June	710	55:05	13:35	90:00	1:45	316	266.50	94	3,585	1,245
July	782	63:20	16:30	89:10	3:00	331	282.25	107	4,975	1,276
August	1458	61:50	15:50	90:00	2:15	341	258.50	129	3,150	1,388
September	853	57:10	11:05	84:05	1:15	338	184.00	79	3,105	1,186
TOTALS	3803	237:25	57:00	353:15	8:15	1326	991.25	409	14,815	5,095.

The Fresno Westside Mosquito Abatement District covers an area of 1325 square miles. This District at present is divided into two parts, with a foreman assigned to each division. The division foremen are under the immediate supervision of the superintendent. The two divisions are subdivided into 13 zones. An operator is assigned to each zone under the immediate supervision of a division foreman. Of the 13 zones within the District only ten are used in this evaluation. These zones are the most important in mosquito production with relation to people and livestock.

The months of June, July, August and September are used since they are the most productive mosquito months.

Before the operators go into their zones they receive copies of the daily control report form and add their names, number of the zone, the date and the speedometer reading. As the operators work their zones they write on the control report, in proper sequence, their activities.

The information for this project was developed by recording ten important categories of mosquito control work (time was recorded in hours): (1) acres treated by aircraft, (2) inspection time, (3) spray time, (4) general time, (5) shop time, (6) stops or inspections, (7) gallons of mixed insecticide used, (8) acres treated, (9) square feet treated by ground equipment, and (10) mileage. Ground vehicles were used to accomplish the last nine categories. Table 1 is an example of monthly totals using reports from Zone 1.

In order to compare the workload of each zone a method was used that transforms the original unit measurements of the various workloads (categories) into indicies. The index was calculated by using the totals for each category for the 10 important zones. For example, the total acres treated by aircraft for the four months selected in 1968 in all 10 zones were 106,985 acres. This is converted into a "unit index" by dividing the total acres into 100 (i.e., 100 ÷

Table 2. Zone evaluations (activities and workload) 1968, Fresno Westside Mosquito Abatement District.

ZONES	1	2	3	4	5	6	7	8	9	10	Unit Index
Acres Treated Aircraft	3.42	13.9	18.1	14.4	10.2	5.6	17.7	5.8	6.1	2.0	.0009
HOURS											
Inspection	8.3	8.3	12.0	8.5	12.6	8.6	16.4	8.0	12.2	8.0	.350
Spray	13.9	10.8	7.0	22.3	4.5	20.6	1.7	6.8	8.9	4.0	.240
General	13.8	11.3	8.8	10.5	7.8	10.3	8.3	11.6	7.7	11.6	.038
Shop	10.7	7.1	9.8	6.8	5.0	4.2	11.0	24.0	19.5	14.3	1.3
Stops or Inspections	11.9	9.4	7.5	10.5	8.1	9.9	14.1	10.4	11.2	8.7	.009
Gallons Mixed Insecticide	13.9	17.4	14.2	25.8	4.4	11.5	1.7	1.9	7.2	4.5	.014
Acres Treated by Ground Sprayers	18.8	20.8	20.4	13.9	6.6	12.8	1.1	1.6	8.9	5.4	.046
Sq. Ft. Treated by Ground Sprayers	4.4	15.7	.34	13.6	4.0	3.3	3.2	38.1	42.8	13.1	.0003
Mileage	13.2	10.9	11.5	7.6	9.4	9.4	11.0	15.7	9.9	11.2	.0026
Percentage or Final Evaluation 1968	11.2	12.6	10.9	13.4	7.3	9.6	8.6	12.4	13.4	7.1	---107%
Percentage or Final Evaluation 1967	8.3	9.6	7.1	11.0	5.5	9.1	9.0	11.4	11.2	8.3	---99.9%

106985 = 0.0009). The unit index shown opposite each category in Table 2 was derived by this method. The unit index (which changes very little from year to year) is then used to calculate the percent of each work or operations category in each zone. This is derived by multiplying the unit index opposite each category by the total units of work recorded in each category in each zone (i.e., for Zone 1, 0.0009 X 3803 = 3.42) (see Tables 1 and 2). The percentage of final evaluation of the zone is obtained by adding together each of the percents shown under each category and then dividing the total by 10 categories (i.e., 3.42 + 8.3 + 13.9 + 13.8 + 10.7 + 11.9 + 13.9 + 18.8 + 4.4 + 13.2 ÷ 10 = 11.2) (see Table 2).

The data obtained by this method (Table 2) will show the difference in the workload in each zone (by comparing final evaluations for each zone) and the operations or categories of work within zones can be adjusted to equalize the workload and improve the efficiency of control operations.

FORMULA: A = 100; B = 100 ÷ A; D = BXC; X = E ÷ F.

CODE:
- X = percentage or final zone evaluation
- A = total units per category for 10 zones
- B = unit index
- C = total units per category per zone
- D = percent each category
- E = total percent all categories per zone
- F = number of categories per zone

100 – arbitrarily selected number used to convert each category into an index number.

FIELD OBSERVATIONS OF ORGANOPHOSPHATE DRIP SYSTEMS APPLIED TO WASTE WATER STABILIZATION LAGOONS IN SAN JOAQUIN COUNTY

James Mallars, and Lester R. Brumbaugh

San Joaquin Mosquito Abatement District, Stockton

Renewed interest in the calibrated method of applying insecticides to flowing and impounded waters has stimulated increased usage of organophosphate drip system methods in California mosquito control agencies. Geib and Smith (1949), and Smith and Geib (1949) reported the use of DDT emulsions in flowing water to control mosquitoes in rice fields and irrigated pastures. Mulla and Darwazeh (1968) in detailed studies with drip systems in pastures indicated promising results with organophosphates. Sjogren and Mulla (1968) achieved effective and economical control of mosquitoes in flowing and quiescent waters by the drip method utilizing Dursban®, fenthion and ABATE®.

Methods and Materials

Navy surplus, five gallon, stainless steel survival drums were utilized to dispense the insecticide emulsions. The drums were fitted with quarter-inch elbows and nipples to which plastic hose was clamped, whereby the emulsion levels within the drum could be observed at any time. The dispensing nozzles consisted of a Spraying System type ¼TT, male connection and type ¼ T female connection. The connections were fitted with Spraying Systems stainless steel orifice No. 4916-29, resulting in a constant head flow. The required amount of emulsifiable concentrate was added to the five-gallon drum, which was then filled with water and agitated to thoroughly mix the emulsions. The resulting five-gallon emulsions were thus dispensed to the mosquito sources over a period of 18 hours. ABATE and fenthion were the two organophosphates utilized in all applications. Ten pre-treatment and post-treatment samples were established at all sites to determine the effectiveness of the drip methods. Additional sampling was also conducted at ideal static areas of lagoons to further evaluate the effectiveness of drip treatments. Evaluations were made 24 hours and 48 hours after treatment. At three treatment sites rates of flow were taken from the daily records at the treatment plant pump stations. At two sites, since rates of flow data were not available, application was made in pounds per surface acre of lagoons. Emulsifiable formulations were applied by the drip method either at the inlet pipes to lagoons, at the pumps or at the clarifier. Two sites were also treated by direct introduction of the concentrate, "slugging" the water at the inlets to ponds.

Treatment Sites and Observations: Both the drip method and the "slugging" method were applied to tomato effluent at the Tri-Valley Canners waste water stabilization lagoons. The drip method was applied to two series of ponds serviced by two separate pipelines. One ponding system consisting of five lagoons contained heavy surface scum of tomato skins, while the other system consisting of two lagoons contained only effluent. One hundred percent mortality of *Culex peus* larvae and *Culex pipiens* larvae occurred in both systems in 24 hours at 0.1 parts per million (ppm) based on a flow of 2.1 million gallons per day (mgd). In the third system a drip tank was installed on the suction side of a pump, introducing the emulsion into the line by a copper tubing connection. The effluent is discharged to a 20-acre field by sprinklers installed at 20-foot intervals. The emulsion was introduced over a period of 30 minutes at a rate of 0.1 pound per acre and the pump then shut off for four hours. Larval mortality was consistently 100%. The sprinkled effluent then discharges from the field by a return ditch to a 6-mile drainage channel. The drainage channel was "slugged" at 0.1 pound per acre at three equal points along the

Table 1. Fenthion and ABATE drip applied to Tri-Valley Canners lagoons (20 acres). Average number of larvae /10 dips.

Application Period & Date	Rate PPM	lbs/Acre	Pre-Treat	Post-Treat (48 hr)	% Control
Lagoons					
18 hours (8-21-68) ABATE	0.1		136	0	100
18 hours (8-30-68) Fenthion	0.1		240	0	100
18 hours (9-11-68) Fenthion	0.1		92	0	100
18 hours (9-23-68) Fenthion	0.1		131	0	100
18 hours (9-30-68) Fenthion	0.1		64	0	100
18 hours (10- 9-68) Fenthion	0.1		193	0	100
18 hours (10-16-68) Fenthion	0.1		84	0	100
18 hours (10-28-68) Fenthion	0.1		114	0	100
Sprinkler System (20 Acres)					
30 minutes (8-21-68) Fenthion		0.1	41	0	100
30 minutes (8-30-68) Fenthion			68	0	100
30 minutes (9- 6-68) Fenthion			120	0	100
30 minutes (9-23-68) Fenthion			136	0	100
Drainage Channel-6 Mi. (30 Acres)					
Slugging Fenthion		0.1	231	0	100
Slugging Fenthion		0.1	146	0	100
Slugging Fenthion		0.1	220	0	100
Slugging Fenthion		0.1	187	0	100
Slugging Fenthion		0.1	146	0	100
Slugging Fenthion		0.1	98	0	100
Slugging Fenthion		0.1	72	0	100
Slugging Fenthion		0.1	141	0	100

Table 2. Fenthion and ABATE drip applied to Simpson-Lee Paper Company lagoons (10.2 acres). Average number of larvae per 10 dips.

Application Period & Date	Rate PPM	Pre-Treat	Post-Treat (48 hr)	% Control
18 hours (8-21-68) ABATE	0.1	47	0	100
18 hours (8-28-68) Fenthion	0.1	180	0	100
18 hours (9- 5-68) Fenthion	0.1	93	0	100
18 hours (9-12-68) Fenthion	0.1	211	0	100
18 hours (9-20-68) Fenthion	0.1	139	0	100
18 hours (9-26-68) Fenthion	0.1	103	0	100
18 hours (10-10-68) Fenthion	0.1	243	0	100

Table 3. Fenthion and ABATE drip applied to Riverbank oxidation ponds (30 acres). Average number of larvae/10 dips.

Application Period & Date	Rate (lbs/Acre)	Pre-Treat	Post-Treat (48 hr)	% Control
"Slugging" (8-21-68) ABATE	0.1	168	24	86
"Slugging" (8-29-68) ABATE	0.1	132	0	100
"Slugging" (9- 4-68) Fenthion	0.1	211	0	100
"Slugging" (9-12-68) Fenthion	0.1	107	0	100
"Slugging" (9-20-68) Fenthion	0.1	93	0	100
"Slugging" (10- 3-68) Fenthion	0.1	119	0	100
"Slugging" (10-10-68) Fenthion	0.1	126	0	100

Table 4. Fenthion drip applied to Tracy oxidation lagoons (65 acres). Average number of larvae/10 dips.

Application Period & Date	Rate (PPM)	Pre–Treat	Post–Treat	% Control
"Slugging" (10- 2-68)	0.1	64	6	90
"Slugging" (10-11-68)	0.1	83	0	100
"Slugging" (10-25-68)	0.1	78	0	100

6 mile interval, resulting in 100% mortality of larvae. Prior to the use of the drip method complete control in the channel was difficult because of heavy weed growth.

The second site consisted of the Simpson-Lee Paper Co. waste water lagoons consisting of titanium effluent, which produces high concentrations of *Culex tarsalis* and *Culex peus*. The emulsifiable formulations were introduced at the discharge well of the clarifier, which discharges into a series of five ponds. The effluent progressively enters each pond through weir gates at the lower end of each pond. Mortalities in the upper three ponds reached 100% in 24 hours and 100% in 48 hours in the two lower ponds at an application rate of 0.1 ppm based on a flow of 1.8 mgd.

The third site consisted of the Riverbank Sewage Ponds. The system discharges to an Imhoff tank and then to lagoons. Heavy organic surface scum constitutes a problem in the industrial lagoons and occasionally in the domestic effluent lagoons. Emulsifiable formulations were introduced into the lagoons by "slugging" at a rate of 0.1 pound per acre at the inlet boxes to lagoons. On the first application complete mortality did not occur in the large 30-acre industrial lagoon at the west end, which is the most distant point from the inlet box. A pump well at the west end of the lagoon discharges water from a nearby orchard underground tile system into the lagoon. On subsequent applications the insecticide formulation was split by introducing 2/3 at the inlet box and 1/3 at the pump well resulting in 100% mortality.

The fourth site consisted of the city of Tracy oxidation lagooning system which includes primary and secondary treatment. The 37-acre domestic lagoon which is maintained weed-free does not produce mosquitoes. The 65-acre industrial lagoon receiving cannery effluent, although weed-free, produces low concentrations of mosquito larvae. Emulsifiable formulations were introduced into the industrial lagoon at a rate of 0.1 ppm based on a flow of 2 mgd per day. The industrial lagoon is levied by an arc-shaped levee within, so that a lagoon occurs within a lagoon, so to speak. Similar to the Riverbank experience, complete mortality did not occur in the inner lagoon on the first application which was made at the inlet pump box. Subsequent applications were again split by introducing ¾ of the emulsifiable formulation at the inlet pump box and ¼ at a point over a subsurface culvert, allowing inflow to the inner lagoon. It is noteworthy that no evidence of water flow is apparent in the vicinity of the sub-surface culvert.

Discussion and Conclusions

Field observations indicated no appreciable differences on the efficacy of ABATE and fenthion. After treatments new larval populations were observed in the lagoons within a short time (Tables 1, 2, 3, 4), hence, extended residual activity was not apparent as observed by others using Dursban. Although LC_{50} levels for *Culex peus* and *Culex pipiens* in the District indicate "vigor tolerance" the low rates of organophosphates applied afforded excellent control. It is also apparent that economical and practical control of mosquito larvae may be achieved by the drip method in the presence of high organic content and often excessive weed growth in contrast to the extended man hours required by the use of conventional equipment.

Safety features must be considered at all times with regard to animals, inquisitive people and children. At the Tri-Valley Canners two drip drums were placed within the pump houses and marked with poison labels. One drum placed on the inlet levee was constantly patrolled by the water tender, assuring a high degree of safety at this location.

The drum at Simpson–Lee Paper Company was installed out of sight within the well of the clarifier, which is protected by a metal fence and gate. Obviously, it is also a wise procedure to notify the agency involved of your activities in use of the drip method.

Where young people visit or bicycle through the area or where protective fences, etc., are not available perhaps the "slugging" method is apropos.

Other considerations include evaluation of the system as to whether it is a total impoundment or whether it discharges to the river, sloughs or other channels where other implications may arise.

References Cited

Geib, A.F. and G.F. Smith. 1949. A preliminary report on the use of DDT emulsifiable concentrate by a modified drip method for *Aedes* control. Mosq. News 9(1):10-13.

Mulla, M.S., H.A. Darwazeh, A.F. Geib and W.E. Westlake. 1969. Control of pasture *Aedes* mosquitoes by dripping larvicides into flowing water with notes on residues in pasture habitat. J. Econ. Entomol. 62:365-370.

Mulla, M.S., and R.D. Sjogren. 1968. Drip application of three organophosphorus insecticides for mosquito control. Mosq. News 28(2):172-177.

Smith G.F., and A.F. Geib. 1949. Control of *Aedes* mosquitoes by direct introduction of DDT into irrigation waters. J. Econ. Entomol. 42(5):835.

TARGET ORGANISMS

Melvin L. Oldham

Tehama County Mosquito Abatement District, Red Bluff

Looking into the crystal ball often allows our imagination to wander in all sorts of directions, however, when crystal gazing in regard to target organisms for mosquito abatement districts we face some items that seem pretty definite.

First of all it appears that we are faced with two types of organisms. One of them has been with us for a long while and has multiplied our various problems many times in the last ten years or so. It is also the cause of 90% of our problems. It is predicted that this organism - the human organism - will double in population in California by the year 2000.

The result of this doubling of population will cause a migration, which has already started, to outlying areas in all parts of California and the balance of population will shift gradually from the southern parts of the state to the northern parts. The work week will lower to 28 hours, leaving more time for recreation which will amount to man-days of recreation 5 to 7 times what it is currently. The food desires, and I say desires not requirements, of this expanding population staggers the imagination. The other factor, waste, is already giving us trouble. Imagine what it will be like when we produce 200 million tons per year of it in the year 2000.

The other "organism" of course is the vector. More accurately I should call it vectors. We are already thoroughly acquainted with mosquitoes and we are getting well into the control of midges, gnats, flies and yellowjackets. Other insects or vectors that may fall into our bailiwick in the future, but which we shudder at now, are fleas, ticks, wasps, wild bees, conenose bugs and the most miserable of all -- rats. No doubt this list could be lengthened by all the managers and entomologists here today but if we can keep up with just this many we will be doing well.

Now putting the two "organisms" together I think pretty well outlines the future for mosquito abatement districts and definitely indicates that we have our work cut out for us. Migration of people into areas of high vector population will put additional burden on MADs for more efficient and effective control of our present vectors as well as including more of the pests that are not now our immediate problems. We are just entering this aspect of the future evidenced by the service requests we receive from people who have just moved from the big cities to the suburban or rural areas. They encounter in a few days more varieties of pests than they encountered in a whole lifetime of city dwelling. I venture to say that almost every MAD represented here today has had service requests in the last 5 years that they would not have dreamed of having 10 years ago. This comes under the title of public tolerance and we have all experienced it. Like it or not it is with us now and will be more so in the future.

Agriculture already highly intensified in parts of the Central Valley will have to intensify even more throughout the valley to produce the food and fodder demanded by the burgeoning population. This will require development of additional agricultural land and water, much of it marginal, which will be prime mosquito sources unless carefully planned and managed. Surburban living immediately adjacent to these agricultural areas will require us to be on our toes in our control activities. Our ray of light in this case will be that land and water values will be so great that the farmer simply cannot afford to have very much of his land devoted to mosquito production.

Water development, well under way throughout the state, will assist considerably the agricultural expansion, but also tied in closely with water development is the increased recreation time mentioned earlier and what I would term "recreational living." Consider man-made water impoundments varying in size from 5 acres to many square miles and in depth from a few feet to several hundred feet. The people living on the shores of these ponds and lakes whether living there permanently or on a recreational outing will expect and demand a certain amount of protection and freedom from aquatic midges and gnats. Clear Lake and the Clear Lake gnat is a prime example of this problem that has been with us for several years. Recently many other impoundments in the north and the south have developed similiar problems. Actually controls for these pests are needed now so we will be prepared when the future intensifies and aggravates them.

These impoundments are not created solely for the impoundment but are merely the beginning of a vast distribution system developed or soon to be developed to deliver water to nearly all parts of the state. This indicates that if the people cannot come to the water the water will be taken to them for their use and enjoyment. Our concern will be to try and keep the area around it vector free.

Recreational living is also bringing people into areas not so closely associated with water but still where there are plenty of possible vectors. Surburban foothill and low mountain valleys have become popular residential areas in this affluent society and the future indicates that this trend will continue. This brings into our future ticks, wasps, wild bees, conenose bugs and false chinch bugs to name a few. These are not new pests, they have always been with us but have been no problem except when humans invade their territory. This territorial invasion is now under way and we will be called upon to assist the invaders.

One ultimate result of civilization's activity is waste -- 75 million tons per year in California now, 115 million tons in 1980, 140 million tons by 1990 and 200 million at the turn of the century. Our concern with this is obvious because almost inescapably flies and rats are associated with waste. Some of us are already heavily involved with flies and more of us will be as time goes on.

I believe we have been tempted in the last year or two in the field of rat control but so far there are no takers, however, our time will come. Since rats are involved in every phase of our food supply from beginning to end, the destructive and disease potential of rats will create public demand for protection from these pests and we will most likely be the chosen ones.

Returning momentarily to our current primary concern -- mosquitoes -- the future holds some changes for them. I predict that change and increased efficiency in land use, urbanization of rural areas and development of new areas will change considerably the species of mosquitoes in some of the areas we now control. *Aedes* sources because of subdivisions will no longer exist. In their place will be *Culex* species in gutters, catch basins and small back yard sources. It is not inconceivable that with intensive development and modification in certain areas of California some species of mosquitoes will be eradicated. In this case the MADs involved will have to shift emphasis or migrate, so to speak, to other vectors.

The one definite exception to this possibility is in the rice producing areas of California. Rice is a valuable portion of the state economy and it is unlikely that it will be eliminated. Unless alternate methods are developed for rice production it will continue to be choice mosquito habitat and source. Our future here lies in adequate research to discover the ways and means to control the rice field mosquitoes.

In short summary, the California mosquito abatement districts' activities and their target organisms are in for some very interesting changes and modifications and advancements during the next 30 years, triggered by an expanding migrating population with very little tolerance for mosquitoes, gnats, flies, rats and numerous other pests. We will most likely be engaged in control activities not even dreamed of in the past.

The past 10 years have given us a slight indication of the possibilities, the next 10 years will really open our eyes and get us under way and by 1980 if we are not in full swing we will not make it. I believe it will behoove us to seriously consider, as it applies to us, one of the basic tenets of ecology - adapt, migrate or die. A mosquito abatement district cannot migrate very far so this leaves us two alternatives, one of which is unacceptable.

TECHNOLOGICAL REQUIREMENTS FOR FUTURE MOSQUITO AND VECTOR CONTROL PROGRAMS

Howard R. Greenfield

Northern Salinas Valley Mosquito Abatement District
Salinas, California

Gentlemen, the classical definition of technology is the application of scientific knowledge to practical purposes. This definition does not accurately describe the purpose of this paper – to prophetically discuss the developments in scientific knowledge that might be applied to the needs of a service-oriented organization such as a mosquito control district or, more possibly, an arthropod vector control agency. However, it is quite fashionable, as we approach the end of this century, to make "projections", projections of what might occur in program development within vector control agencies based on the scientific developments taking place today.

I would like to introduce the subject assigned me by quoting Norman J. Ream (1968), Special Assistant to the Secretary of the Navy: "We have experienced more rapid technological progress in the past 20 years than in the entire history of the world. Two statistics will emphasize my point. First: At least 85 percent of the technical knowledge that exists in the world today has been developed since 1945. Second: 90 percent of all recognized scientists in the history of the world are alive today."

"The world is faced with an explosive rate of change. The key word is 'rate', for during the next 20 years in our own nation our population's average age will drop from the present 28 years to under 25, and the total population will increase to about 300 million. In these next two decades we must do again what we did in the last 200 years in terms of building homes, schools, universities, hospitals, factories, and other population-oriented facilities. This population explosion will also be accompanied by accelerating rates of change in mental attitudes and ethics. These changes and advances in technology are having an intensive effect on our labor force and on management in the private sector of the economy, and on our government operations and organizational structure."

Mr. Ream has fashioned some very provocative ideas of what the needs will be nationwide as far as population-oriented facilities are concerned. In California, with a projected population of 41 million by the year 2000, no less concern may be expressed. Mr. Ream also stated that reorganization of governmental structures must be done to accommodate the population explosion – signs of which are already occurring at the federal levels. Witness the new Federal Department of Transportation, which has brought together some 35 existing agencies and departments into one super agency. Lynton K. Caldwell (1968), Professor of Government, Indiana University, suggests that the public is becoming increasingly aware of its responsibilities for environmental welfare, and that air pollution, misuse of pesticides, etc. will not long be tolerated. He states that: "The tasks of restoring and maintaining the viability of the environment will require new forms of public relationships and actions." Mr. Caldwell asserts that the possibility now exists that a super department, such as Health, Education and Welfare, will assume full responsibility for a department of human ecology and total management of environmental relationships. We have only to look to our own state to know these predicted changes are occurring, although on a smaller scale. Today we have the Association of Bay Area Governments, the Association of Monterey Bay Area Governments, Regional Air Pollution Control Districts, Regional Urban Renewal Districts and many more too numerous to name. All of this is happening to us, to our nation and to our people through the development of "scientific knowledge" and "applied technology."

We have learned from Mr. Oldham the kinds of "target organisms" that possibly will become the responsibility of all vector control agencies and are today the responsibility of a few districts. It is my opinion that Mr. Oldham is completely in harmony with the projected needs of vector abatement or environmental management of the future. If vector control agencies of the future are to be responsible for the control of many kinds of arthropods and other animals, we must then look to the present body of scientific knowledge to project the technology to the future 20 years or even 30 years from now.

Communication systems, one of the most fantastic scientific research and development projects, will play an ever-increasing part in vector control programs. With an estimated publication rate of scientific papers in excess of 100,000 per year, and constantly increasing, data processing and retrieval systems will be absolute necessities at the federal, state and regional levels.

The development of such data storing and data retrieval systems has already become a scientific fact. Apparently, all that remains to be done is the development of a workable input system to relay necessary environmental information at the local level to the data storage center and then return it to the local agency for use in the control of the target organism for which the information had been requested. It is conceivable that with the development of more sophisticated computer systems, the request for control information from the input end (the local agency) would be examined for conflicts of interest among the many agencies involved with management of environmental control programs. Thus, overkills, fish kills, environmental contaminations, etc., would be avoided or completely eliminated. The indiscriminate pollution of the total environment by man in his quest for whatever man seeks now, fortunately, is being attacked as unnecessary and unwarranted by many concerned individuals, groups, and state and federal agencies. State and federal laws are being passed which restrict the use of many chemicals once considered by many to be the solution to man's efforts to wipe out insect populations. There is no valid reason to believe that legislative actions further restricting the use of broad-spectrum pesticides won't continue to be a "way of life" for the vector control administrator. Consequently, it can be reasoned that the future use of chemical pesticides will of necessity be species-specific and will be applied in the public domain only by licensed technicians. What forms chemical pesticides will take in the next 20 years can be projected on the basis of current research now being conducted. There undoubtedly will be available to the vector control specialist genetic modification chemicals which would, upon application to the target organism, literally eliminate the animal from the ecological niche it occupied. Chemicals known as sex attractants, juvenile hormones and growth regulators will be used against undesirable pests. These bio-chemical compounds now being studied are extremely important, in that they fulfill a basic requirement - that of being species-specific.

Biological controls are also to take their place in the future scheme of things. Considerable interest is currently being expressed about the use of viruses and bacteria as possible control techniques to be used against a specific target organism, and nematologists are now exploring the possibilities of using parasitic nematodes for pest control purposes.

Looking at the research efforts that are being given to the development of chemical control techniques and to the biological control techniques, I believe we can confidently look to the future knowing that there will be at our disposal many tools for the manipulation and management of organisms deemed to be unnecessary or unwanted in man's environment. I must point out, however, that even with the marvelous new materials and techniques that will be at our command and, with the new instruments and machines that will be developed to disseminate, as needed, the viruses, bacteria, sex attractants, species-specific pesticides and other chemical forms yet unknown, planned programming of control efforts through the use of highly sophisticated computers and data memory bank centers will be absolute necessities of the future arthropod vector control agencies.

References Cited

Caldwell, Lynton K. 1968. Restructuring for coordinative policy and action. Public Administration Review. 28(4):302-303.

Ream, Norman J. 1968. The computer and its impact on public organization. Public Administration Review. 28(6):497.

FUTURE MANPOWER NEEDS FOR MOSQUITO ABATEMENT IN CALIFORNIA

A.F. Geib

Kern Mosquito Abatement District, Bakersfield

Are we now properly oriented? We have been told by the previous speakers what has been happening in technological advances and our ever growing population. As the time marches on, most of us may vaguely realize the significance of the ever accelerated pace of development and constant change taking place about us. Only when we focus in on this subject, as we are trying to do here today, do we begin to realize the rate at which these changes are occurring and the impact they are having upon our socio-economic structure. It seems beyond comprehension that during the short span of the past 20 years man has developed newer knowledge equal to or greater than all he had previously acquired during the history of mankind. When you also recognize that the speed of change increases in geometric progression it becomes apparent we must plan ahead 5, 10, 20 and 30 years or more. To do otherwise means we would fall by the way and perhaps eventually end in chaos.

We recognize that predicting the future is at best a tenuous and precarious business. Nevertheless past and current trends can be used as guidelines enabling us to project the future within reasonable limits, barring of course, major disasters.

Using such guidelines we can reasonably expect in the future:

1. Tremendous growth in population.

2. An ever greater concentration of population in urban centers coupled with ever greater mobility.

3. To meet the requirements of increasing population production of more and more food is an absolute necessity.

4. Increasing populations and newer technocracy equating to an ever increasing problem of waste disposal (8 lbs per person per day). How is this to be handled without creating nuisances of major proportions?

Considering the predicted changes which are confronting us now and in the immediate future it seems apparent we must recognize these changes and prepare for them or fall by the way.

In essence man is continually obtaining greater and greater control of his environment while concurrently the populace is demanding more and more freedom from hazard to his well being, nuisances and inconveniences. The modern concept towards our physical environment has progressed away from ignoring problems, or abolishing them, and now centers around solutions and measures for their control. It would seem most likely agencies such as ours will become responsible for fly control, numerous other insect pests of man and animals and even things such as rats. To provide such environmental control as might fall within the future province of mosquito abatement agencies will certainly require specialized and additional manpower. With such a prospect, at least some if not all employees will need broader and more comprehensive training than is customary and acceptable today.

I don't pretend at this time to say what our manpower and scope of training requirements will be in the next 10 years and beyond, rather I believe it appropriate to pose some questions that may stimulate thinking aimed towards finding answers for the problems inevitably appearing upon the horizon.

1. What will our manpower needs be 10 years hence?

2. Can we write adequate job descriptions and how will we go about finding the people qualified to fill these?

3. What will be our needs for professional people? What grade?

4. What should their backgrounds be in sciences, business, liberal arts, engineering?

5. What will be our needs for technicians? What would be the desired scope of their training?

6. What will be the sources of people to fill these jobs – universities, state colleges, community colleges, high school?

7. Can special training be obtained at high school, community colleges and on up through universities?

8. What training and educational level will be needed by the basic operators?

9. Could special refresher courses be developed at local institutions for upgrading personnel?

10. How can in-service training be better developed and accomplished? What are our sources in developing such training programs?

Perhaps the time has come for that first step. Should we have a committee within the association that would develop, with advisory consultation, an outline for a well rounded training program for basic district operators? Could districts, by themselves, with such an outline produce adequately trained personnel? Should this be done jointly, or should we call for outside assistance?

I conclude with these questions, wondering if the time has arrived when we should begin exploring the need for various approaches that might be best utilized for in-service training programs, the scope and type of such training.

COST AND FINANCING

Stephen M. Silveira

Turlock Mosquito Abatement District, Turlock

In my attempt to project costs and financing of mosquito control in California, I became involved in a study of the economic development of California, which was quite revealing to me. We hear and read much about the population explosion, but there is much more. The relentless population growth of California has been matched by expansion of industry, trade and agriculture. Population growth was made possible by the labor demand emanating from a burgeoning economy. Of course, our golden sunshine also played a role in attracting people.

California's enormous growth has been sustained by a number of economic revolutions. First it was the discovery of gold which set the development process in motion. As gold mining faded, we saw the rise of wheat farming and cattle ranching. By the turn of the century, we had diversified agriculture and with it the food processing industry. Then came the lumber, petroleum and manufacturing industries. In manufacturing, we must include the cinema.

Everything was booming until the great depression. In the 30's there was a definite pause in California's economic growth. However, the lean years of the depression incubated the aircraft industry which, with the subsequent aerospace industry, has provided the base for the tremendous

Table 1. Personal income chart, prepared by Economic Research Division, State Savings & Loan Association.

Year	Amount (in millions) United States	Amount (in millions) California	Per Capita Income United States	Per Capita Income California	California as percent of U.S.
1965	$538,893	$60,234	$2,765	$3,274	118.41
1966	$586,845	$65,208	$2,978	$3,468	116.45
1967	$628,815	$70,204	$3,159	$3,665	116.02
1968	$685,000	$75,985	$3,405	$3,905	114.68
1969	$727,200	$80,900	$3,580	$4,095	114.39

Table 2. Projected employment for California region (in thousands).

Item	YEAR 1965	1980	2000	2020
Total Population	18,106	25,465	38,181	54,941
Armed Forces	308	291	291	291
Civilian Population	17,798	25,174	37,890	54,650
(Civilian Employment – Population Ratio)	(.383)	(.403)	(.406)	(.406)
Total Civilian Employment	6,825.4	10,137.3	15,369.1	22,187.9
Employment: Basic Industries	2,022.5	2,745.5	3,669.2	4,717.5
Agriculture, Forestry and Fisheries	276.7	267.0	254.2	241.4
Mining	27.1	28.0	29.9	30.8
Manufacturing	1,718.7	2,450.5	3,385.1	4,445.3
Food & Kindred Products	182.4	205.5	235.0	268.8
Textile Mill Products	9.9	11.4	12.2	12.2
Chemical & Allied Products	58.0	87.7	128.7	167.7
Paper & Allied Products	30.8	46.3	68.9	89.3
Petroleum Refining	35.7	28.8	21.3	15.5
Primary Metals	64.5	92.8	124.2	152.4
Other Manufacturing	1,337.4	1,978.0	2,794.8	3,739.4
Employment: Service Industries	4,802.9	7,391.8	11,699.9	17,470.4

Note: Preliminary – subject to revision.

Taken from Information supplied by the Calif. Dept. Water Resources 12/10/68

economic and population growth since 1940; a growth rate undreamed of prior to that time.

California's consistently rapid development over the past 100 years has been stimulated by four distinct surges. Broadly stated, they were mineral resources, agricultural and vegetable resources, diversified manufacturing and a complex of industries we call "aerospace." What industry will be responsible for the fifth surge that is capable of providing a major growth impetus? We cannot yet identify "X", but we can be sure it's coming.

I give you this quick view of the economic history of California to impress you with the dynamic growth forces in this state. What do these dynamic growth forces have to do with us? It is obvious that these same forces will set the pattern for our future growth and development. The aerospace and electronic industries are mainly responsible for our rapid economic growth in the past 20 years. Both are highly sophisticated industries with high-skill labor requirements. I look for industry "X", which will provide the next economic surge in California, to be more sophisticated in

Table 3. California nonagricultural wage and salary employment, 1955, 1965 and forecast for 1975 (in thousands). Prepared by the California State Office of Planning 1968.

	1955	1965	1975	Total Change 1965-75	Percentage change 1955-65	1965-75
Total Wage and Salary Employment	4,082.9	5,774.5	7,977.2	2,202.7	41.4	38.1
Goods Producing Industries	1,441.8	1,766.0	2,055.0	289.0	22.5	16.4
Mineral Extraction	36.8	31.8	21.0	-10.8	-13.6	-34.0
Construction	284.0	325.9	336.0	10.1	14.8	3.1
Manufacturing	1,121.1	1,408.3	1,698.0	289.7	25.6	20.6
Service Producing Industry	2,641.1	4,008.5	5,922.2	1,913.7	51.2	47.7
Transportation, Communication, Utilities	347.4	386.9	391.4	4.5	11.4	1.2
Trade	915.6	1,274.3	1,774.7	500.4	39.2	39.3
Finance, Insurance, Real Estate	180.4	310.5	485.2	174.7	72.1	56.3
Services	516.5	932.0	1,400.5	468.5	80.4	50.3
Government	681.2	1,104.8	1,870.3	765.5	62.2	69.3

Note: The projections in this table are experimental and pending further testing of the model from which they were derived should not be used for planning purposes. Prepared by the California State Office of Planning 1968.

personnel and technological requirements than our present aerospace industries. Such industries have and will continue to set the pace for California. They are partially responsible for the higher-than-average salary and wage levels in California (Table 1).

Agriculture, despite sizable growth, has been supplanted by manufacturing as the most important contributor to state wage and salary payments. This industry will continue to lose large numbers of people as far into the future as we can see (Table 2). Agriculture, however, will remain an important basic industry as long as people must eat.

With our industrial development in California will come the megalopolis; the boundless communities of many communities. Small towns will grow large, join and become cities as large as counties are now. We may see a new type of community, neither urban nor rural. Modern futurists call it "the functional multi-county community of tomorrow that blends the economic and cultural opportunities of affluent metropolitan life with the space and beauty of the country-side." Such developments will certainly change our current property tax structure. There is a clamor now for property tax reform. Currently there are three far reaching property tax reforms being studied by our state planners. Public agencies, such as mosquito abatement districts, will surely be affected.

As our industrial base is expanded in California, we can expect a more affluent society with more leisure time. As our people become more affluent, they become less tolerant of annoying insects, foul air, polluted water, and countless other things that threaten their well being and security. Government will be required to enhance the utilization of the environment by an expanding population.

In our own field of mosquito control, we will be required to free the environment of insects and other organisms which threaten the public comfort as well as public health. We will be asked to achieve acceptable levels of control where people work, live and play.

Will funds be available to provide all the services the public will expect from our tax-supported agencies? Current indications are they will be available to those public agencies which have planned and developed the technology necessary for economical and effective solutions to problems that develop in their own areas of responsibility. The currently available wage and salary employment projections for California (Table 3) indicate a progressively stronger economy as we increase our industrial base. I must inject a word of caution. The projections presented in Tables 2 and 3 are preliminary and are subject to revisions by the agencies which developed them. They should not be used for detailed planning but are included here as indicators of future trends. More sophisticated economy models are being developed by the University of California and others for California and for sectors of California, which should prove valuable.

It is readily apparent from these tables that the trend in California is for rapid and intensive growth. The next logical step would be to relate the impact of California's projected economic growth to mosquito control. I think this is a worthwhile endeavor and should be undertaken. By accurately projecting into the future, we can predict generally what it holds for us. From such information, we can develop a general plan which would be a statement of what it is that we, as mosquito control agencies, can and would like to become in 1980, 2000 and 2020.

WHY TRUSTEES SHOULD BE CONCERNED WITH NATIONAL AND INTERNATIONAL MOSQUITO CONTROL PROGRAMS

Thomas D. Mulhern

California State Department of Public Health, Fresno

When we speak of mosquito-borne diseases in California we are usually thinking of encephalitis and malaria – specific causes of human illness of continuing concern.

Extensive malaria mosquito sources are characteristic of the Sacramento Valley, and lesser sources occur frequently elsewhere in the State. While there has been no indigenous malaria in California since 1957, during the prolonged period of the Vietnam conflict we have seen a significant number of imported cases and there exists a continuing potential for outbreaks. However, we feel confident that prompt remedial action can minimize any such outbreak of malaria that may occur.

There can be no such confidence with respect to encephalitis. Sources of the principal encephalitis vector, *Culex tarsalis*, are distributed throughout California, perhaps as widely as the sources of any other mosquito, and the viruses are enzootic in the bird population. Fortunately, human cases of this disease have been at a low ebb for several years, including 1967 when surveillance indicated that there was cause for concern and mosquito control agencies took extraordinary measures to control vectors within their jurisdictions.

There is a meaning to the word "dis-ease" not directly related to specific infections. It is an archaic meaning but very pertinent to our discussion. Webster's Unabridged Dictionary offers the following definition: "Dis-ease: lack of ease, discomfort, uneasiness, trouble." A quotation from Spencer's Faerie Queen is as follows: "So all that night they passed in great disease." When the word "dis-ease" is written with a hyphen the relationship of mosquitoes to disease becomes clear. This is an ancient word, but quite appropriate because the mosquitoes have been around since the time of the dinosaurs. The dinosaurs are long gone but the more adaptable mosquitoes are still with us and still ready, willing and able to help us pass the time in great dis-ease, by night or day.

The extent of the problem of controlling this form of "dis-ease" is indicated by the fact that mosquito control agencies will probably spray nearly 2,500 square miles of mosquito sources in 1969 to prevent the emergence of mosquitoes. As we begin the year 1969 there are some 60 local agencies engaged in mosquito control in California. The area served is about 40,000 square miles and the annual expenditure amounts to nearly $9,000,000. The efficacy of this program is shown by the fact that people in the valleys where mosquito sources are abundant may still freely use the out-of-doors for pleasant living and recreation throughout the summer months.

The sources in which the mosquitoes occur are many and varied. Some are of natural origin, including rain water and snow water pools, runoff and overflow from streams, swamps, fresh water and salt water marshes, inundated tide lands, shallow edges of lakes and ponds which are colonized by aquatic vegetation, springs, seepages, and holes in trees. However, man-made sources predominate, and these may be characterized as residential or community sources, industrial sources, agricultural sources, and water resources development sources.

The residential or community sources include street drainage catch basins, poorly graded gutters, containers in yards or on dumps, neglected bird baths, unused wading or swimming pools and the plastic covers sometimes used with them, runoff from lawn and garden irrigation, leaky pipes resulting in pools under or nearby houses, cooler or airconditioner drain water, improperly designed individual sewage disposal facilities and kitchen drains, and improperly operated community sewage effluent disposal works.

Industrial sources include liquid waste disposal ponds or lagoons such as those at wineries, canneries, dairies, and saw mills.

Agricultural sources include mainly irrigation water which stands too long in the fields, as in poorly leveled pastures. However, there is a considerable variety of other agricultural sources, ranging from small leaks at irrigation valves to such large sources as rice fields. Poorly constructed or poorly maintained irrigation and drain ditches frequently produce mosquitoes. Pools of washwater from dairy barns may support vast numbers of mosquitoes. Farm ponds, sewage and seepage from irrigation systems can be important sources. The agricultural sources account for probably 60 to 75% of the expenditures for mosquito control in California, most of this being related to faulty irrigation practices. This is a difficult problem since irrigation is essential to agriculture and agriculture is a primary source of income for much of the State.

Mosquito sources resulting from water resources developments occur chiefly where reservoirs are not properly designed or maintained, in waterways that are not kept free of aquatic weeds, or in seepages or leaks that often occur along canal rights-of-way. The agencies which have primary responsibility for the maintenance and operation of such works logically should provide for the control of mosquitoes which occur therein, and frequently do so by contracting with a local mosquito control agency to provide surveillance and control as necessary.

The problems vary from district to district, and the resources available also differ, sometimes substantially. As one might expect, applying the available resources to the local problems result in programs which differ, even between adjacent districts.

I should like to offer a thumb-nail sketch, comparing the mosquito abatement districts of 1949 with those of 1969. This is not a description of any specific district, but a composite outline of characteristic features of many districts.

In 1949, when I came to California, many of the districts had been organized or substantially increased in area within the previous three or four years. Most of the members of the new boards of trustees had little if any previous knowledge of mosquito control and they were still trying to determine how they could best serve their respective jurisdictions in providing policy guidance to obtain effective and economical operations. The typical district was quartered in surplus army buildings or somewhat dilapidated rented garage buildings, all of which were generally hot in the summer and cold in the winter. Vehicles were mostly well worn surplus military jeeps and weapons carriers, subject to frequent breakdowns. Many of the spray machines were jerried-up units, put together at minimum cost from surplus parts with much ingenuity, but not providing too much in terms of reliability. There were great stacks of surplus military insecticides in rusty cans and drums, some of which had been to the South Pacific and back and were of somewhat doubtful value. Even the mosquito light traps available were hand-me-downs from the U.S. Public Health Service, usually operating at about 25% mechanical efficiency. The mosquito sources were not completely charted, maps were not adequate, record keeping systems were in a state of partial development, training of many kinds was being undertaken in an effort to convert untrained labor into effective mosquito control operators. Very few aircraft were in use. As midsummer approached it was common for larviciding programs to fall behind schedule, and thermal aerosol fogs were used extensively in an often unsuccessful effort to control mosquitoes which had invaded the residential areas. The information available about the geographic and seasonal distribution of important mosquito species was quite incomplete, and behavior patterns were only partly understood. Taxable values were still low, and although many agencies were receiving financial aid through state subventions and assessing at a 15 cents/$100 tax rate, funds were still insufficient in many districts. By the end of the mosquito season, frustrations added to frustrations tended to destroy the morale of the working forces.

Each succeeding year brought cumulative improvements, so that the model districts of 1969 may be characterized as follows: Boards of trustees are now composed mainly of well-seasoned members, secure in their ability to provide policy guidance, and highly sensitive to the demands of their constituents for constantly improving mosquito control. The headquarters facilities are designed for maximum efficiency of current operations and with provisions to accommodate expansions which are likely to take place within the next 20 years. The buildings are attractive and well-maintained. District personnel have accumulated long experience, personnel are characteristically highly trained for their respective assignments, and there is a stability of organization and high morale apparent even to casual visitors. The equipment is of high quality, reliable in service, and selected or custom built especially for the service expected of it. Insecticides are thoroughly tested, the sources of mosquitoes are charted and mapped, records are kept in great detail, and spray operations are carried out with dispatch and precision. Each agency has its own well-trained mechanics and an efficient equipment maintenance program. Operational equipment is depreciated and replaced on a schedule which avoids breakdowns and excessive maintenance costs. Although labor and materials costs are substantially higher, many operations are performed at lower unit costs through the employment of more efficient machines, more reliable insecticides and better trained workers in a program more directly focused on the problem. There are sufficient reserves available so that emergency measures can be supported to avert mosquito-borne disease epidemics when the early season warning system indicates that emergency action is indicated. In many districts, this progress has been accompanied by a gradually declining tax rate.

One may well ask how this improvement has been brought about. There is of course no simple, easy answer. One major factor has been the judicious application of information and techniques obtained from many sources to the solution of the respective local problems.

A successful technical program calls for a well-informed director who can adopt or adapt procedures developed in other related programs. If one will examine any highly sucussful program it usually becomes apparent that its unique features are those of planning, making use of existing information and extracting the most from precision equipment and carefully selected materials. This then is management – the utilization of the best resources available for the task to be performed.

Perhaps in no other public effort are these principles better illustrated than in local mosquito control programs in California. Equipment, insecticide formulations, and budget procedures are similar in many districts – yet no two programs are identical, for each is adapted to its special needs. Furthermore, the programs are not static. What was good enough last year may be discarded next year in favor of a better device or procedure developed in a neighboring area. Out of this constant striving for improvement has come the extremely high level of effective mosquito control programs. The University of California is helping by performing research to find new or improved mosquito control measures, and the Bureau of Vector Control and Solid Waste Management encourages and performs technical development and evaluation services, as well as facilitating the exchange of information relative to promising new developments.

Let us look at some of the tools and materials of the trade, which are so commonly accepted as to be taken for granted, and consider where they came from.

In 1892 Dr. L.O. Howard, then entomologist for the United States Department of Agriculture, suggested the use of kerosene "coal-oil" as a thin film spread upon the surface of the water where mosquitoes were breeding and so was born the control of mosquitoes by larviciding. We now have had countless other larvicides – but petroleum oils are still useful in the armamentarium of mosquito control weapons.

At the turn of the century, the yellow fever control programs in Cuba and the combined yellow fever and malaria control program in Panama proved conclusively that an efficacious attack against the vectors could control these dread diseases – and it is significant that both are virtually eliminated from the United States. Much closer to home has been the adoption in California of an encephalitis intelligence system and the framework for an emergency operations program that can go into action when the need arises. The efficacy of these procedures has been successfully put to the test during two critical years since the epidemic of 1952.

Current extraordinary precipitation may presage another emergency year, although it is yet too early to make a positive prediction.

The New Jersey Agricultural Experiment Station completed a statewide mosquito survey in 1904, perhaps the best of its kind that has ever been made anywhere, that was useful in fixing the pattern of successful mosquito control in communities for New Jersey and other states. The report assessed the various problems, and in general recommended that a primary program be adopted which would emphasize permanent control (source reduction) and which would employ larviciding as a supplement. The values of mosquito fish, including both brackish and fresh water species, were fairly appraised. A plan was also proposed whereby engineering means would be used in promoting biological control. In this regard, the salt marshes would be ditched, not for drainage but to circulate the waters of the tides, thereby exposing mosquito larvae to attack by fish. Other predators were also recognized. The basic principles enunciated very closely resemble those incorporated in the "Standards and Recommendations for Mosquito Control in California" which were adopted in 1949.

Following the appearance of the 1904 report, the early attempts to provide mosquito control in New Jersey were performed by municipalities, but were not successful because the included areas were too small and invasions of mosquitoes from other areas nullified the results. Then a model mosquito law was passed by the State Legislature, providing for the formation of county-wide "mosquito extermination commissions."

The principle of separating the mosquito control program from party politics, and of providing for continuity of effort by entrusting this important program to a policy Board of Trustees was set forth in 1912 in New Jersey. This principle was adopted with appropriate modifications of details by California in 1916. By this legal device the population which receives the benefits and pays the bills is given control of its own program. By this arrangement the trustees represent the people, the manager represents his profession and personnel, facilities and tools are employed to perform necessary operations within the policies laid down by the Board. Furthermore, although these boards are entrusted with extraordinary legal powers to demand the abatement of public nuisances, the laws have been on the books for more than 50 years with no recorded case of abuse of these powers. Instead, the boards have been extremely responsive to the majority views of the people they represent. The structure of this legal arrangement has been an important factor in allowing the stable development of economical mosquito control in California.

Some time after the value of oil larvicides had been demonstrated, Paris green dust was found to be effective for the control of *Anopheles* larvae. This material was used extensively in Panama, in the southeastern United States, and in due course, for a time in California. Paris green continued in use until it was displaced by DDT and other chlorinated hydrocarbon pesticides. It is of interest that DDT had been synthesized by the Geigy Company of Switzerland long before its extraordinary ability to control mosquitoes was discovered. Thereafter, workers at the USDA laboratories in Orlando, Florida thoroughly explored its potential uses and developed formulae, techniques, and equipment for its efficient utilization. The information developed by the USDA was of inestimable value to the success of the expanded mosquito control programs in California immediately following World War II. Later, many other synthetic insecticide chemicals were developed by many research organizations. Mosquito control agencies in California adopted some of these, including BHC, chlordane, toxaphene, parathion, aldrin, and dieldrin. Still later, commercial laboratories developed malathion, fenthion, and Dursban®, all of which have been adopted and used to good advantage in California.

Thermal aerosol fogs for the control of adult mosquitoes enjoyed a brief period of high popularity in California. It is of interest to recall that much of the initial development of the equipment was carried out by workers from Columbia University, techniques for employing fogs were developed by the USDA, commercial interests developed several machines which are still being produced 20 years later, and California mosquito workers employed the same principles in the design of custom-built fogging machines.

The origin of the mist blowers which are now employed so effectively by mosquito abatement agencies is less easy to trace. However, high volume mist blowers for use in agriculture were thoroughly tested by workers of the USDA and commercial models were available from several manufacturers before 1940. Most of these were too large for convenient use on jeeps. The Northern San Joaquin Mosquito Abatement District was the first to develop a mist blower especially for use on a jeep. A scientific study by the Department of Agricultural Engineering, U.C., Davis, provided technical criteria for the design of improved models, many of which are now in service.

We are now heavily dependent upon aircraft for mosquito control in an area which approaches 1½ million acres annually. We can be proud of the progressive improvements which have been accomplished in the use of aircraft in California, and of the fact that we are now being looked to for leadership in the use of aircraft to control mosquito larvae. But there is in fact not much difference in the procedures which we presently follow and those which were developed by the U.S. Department of Agriculture and by the Tennessee Valley Authority during the period 1942-1947. The early contributions by USDA workers which were published during the same period have been of inestimable value to us in developing the low volume larviciding methodology which is now serving mosquito control in California.

Mosquito control agencies in California have in the past benefited from advances elsewhere, particularly those resulting from research and development by federal agencies. Among those are the Department of Agriculture, the Public Health Service, the Tennessee Valley Authority, and the armed services. Now that the local programs here are so highly developed, there are increasing opportunities to reciprocate by providing information and services to areas of need in other states and other countries.

While research performed by or supported by federal agencies has contributed greatly to the scientific basis of mosquito control, this is not the time to slacken research efforts. The success of spraying operations is now threatened by the development of increasing tolerance of mosquitoes for many of the commonly used insecticides. We cannot even be sure that we will be able to get through the 1969 season without serious breakdowns in chemical control. We need immediate intensified efforts to find or develop additional pesticides for public health purposes. It appears appropriate to encourage the federal government to provide substantial support for this kind of research.

Procedures for clearing the way for federal registration of new pesticides for public health purposes has become a particularly critical problem. It is now estimated that over a million dollars must be invested in tests to demonstrate the safety of a new pesticide before registration will be granted. It is understandable that producers of pesticides are reluctant to make such an investment except where there is an apparent ready market for the product which will justify the expenditure. There are those who believe that special funds should be made available to appropriate agencies to permit them to accelerate research on products which appear to have value in public health programs, but which show limited commercial potential.

Fundamental to the success of rural programs is the development of improved methods for the control of mosquitoes in irrigated agricultural areas. The research necessary to obtain a satisfactory solution to this complex problem will inevitably be both difficult and costly. Consider for example those fields in the Central Valley which in 1968 required larviciding by air something over 20 times during the season at a cost to the district of more than $1,500 per field. It is doubtful if the ranchers made a net profit of that amount from the respective fields. Would it not be appropriate to encourage federal support for joint agricultural-mosquito control research and demonstrations to show how these problem fields could be managed for increased agricultural returns simultaneously with lessened mosquito production?

As you know, federal agencies are permitted to support qualifying research projects conducted at the state or local level, and California mosquito control has benefited greatly during the past three years under a contract between U.C., Davis and the USDA which provided support for studies on low volume spraying. This project was completed in 1968 to the satisfaction of all concerned. However, it did reveal other aspects of air spraying which need to be studied. Regrettably, federal funds for continued support of this research are not available at this time.

There is yet another aspect of federal agency participation which deserves consideration. It has been suggested that matching federal funds be made available under reasonable limitations to states and local communities which have urgent mosquito problems, but insufficient local tax income to support a sound control program. There are many such communities throughout the country, including a few in California. Such communities can often maintain successful, technically sound programs once they are established, but there is urgent need for outside help during the first difficult formative years. Also serious technical mistakes that may occur in programs undertaken without essential scientific guidance invariably reflect unfavorably on properly executed programs.

Federal aid could be of great value in supplementing local effort in certain areas, although such aid should be safeguarded so that only essential programs are eligible, and the determination of eligible projects should be made within the participating states in accordance with existing patterns of administration.

The international programs present a somewhat different consideration. The possibility of eradicating malaria is a realistic goal in many parts of the world. It is true that global turmoil, insecticide resistance and new information on mosquito behavior have threatened success or changed the direction of programs in some areas. Nevertheless the great progress which has been made has substantially lessened the economic penalty of malaria and has cleared the way for accelerated economic development of many areas. The international authorities on malaria have given sober consideration to these complex problems, and there is a gradual evolution of program which is focusing more attention on the comprehensive control of the vector mosquitoes. Within this broadened concept, there is room to apply all of the technology which has been developed for the control of mosquitoes and mosquito-borne diseases.

It has been satisfying to note that workers from other countries have shown great interest in California control programs, and in your Association. It has been even more satisfying to see the favorable response of the many workers from other countries who have been able to visit California's control agencies.

Among all of the kinds of foreign aid which the United States might extend to the less privileged nations of the world, perhaps none could be more beneficial than the elimination of the barrier to progress represented by mosquito-borne diseases. The aid now being provided by the United States, either directly through USAID, or indirectly through contributions to the United Nations of which WHO is one division, is mainly in the form of funds for technical support and guidance – a small fraction of the total effort, but one which produces a substantial return.

There is a long list of persons whose ability to provide technical services to worldwide programs is greater because of their association with the mosquito control programs in California. As the overseas programs embrace a broader application of anti-mosquito measures the demand for persons who can provide such services may be expected to increase. Each new experience tends to make an individual more competent in meeting responsibilities by increasing his insight into mosquito problems beyond those with which he is familiar.

Included in this category are Edgar A. Smith, Russell E. Fontaine, Roy F. Fritz, John O. Stivers, Harry Mathis, William C. Reeves, Richard F. Peters, Lawrence L. Lewallen, Jack H. Kimball, Harold W. Brydon, Edmond C. Loomis, Norman B. Akesson, Arthur F. Geib, Donald H. Green, Edwin G. Washburn, Mir S. Mulla, Ernest C. Bay, Austin W. Morrill, Jr., George S. Stains, John M. Hirst, A. Ralph Barr, Melvin M. Boreham, Ernest G. Meyers, Gerald D. Brooks, Thomas F. McGowan, Albert G. Rudnick, John W. Kliewer, Frederick J. Santana, Bryan T. Whitworth, John N. Belkin, Thomas H.G. Aitken, Douglas J. Gould, Norman G. Gratz, Robert L. Metcalf, Merrill A. Wood, myself, et al.

THE OUTLOOK FOR LOW VOLUME INSECTICIDAL APPLICATIONS IN CALIFORNIA MOSQUITO CONTROL

Thomas D. Mulhern

California State Department of Public Health, Fresno

It is probably appropriate to anticipate that someone will again ask: "Does the report which appeared in 'Science' for December 1968 mean that low volume spraying of organophosphorous pesticides will be banned?" The article referred to reported circumstantial evidence which appears to imply that the aerial release of a nerve gas called "VX" from an aircraft at the U.S. Proving Ground at Dugway, Utah, killed 6000 sheep in flocks that were 27 to 45 miles downwind of the release point. The wind was blowing toward the area where the sheep were located, with gusts up to 35 mph, and the toxicant was released at altitudes from 100 to 1500 feet.

Two comments appear to be apropos: we have only the "Science" report on this matter and the information is both incomplete and circumstantial; and whether the sheep mortality resulted from the reported application or from some other cause should not affect the use of low volume applications of pesticides for mosquito control for the following reasons:

First, the dosage rates which are applied for mosquito control have been shown to be so safe that when people engaged in an experiment with these spray materials happen to be caught directly under the aircraft so as to be sprayed with the normal dosage, no detectable harm occurs. None of us like to be so exposed and all reasonable precautions are taken to avoid contact with the spray because of the inherent hazard due to the cumulative effects of repeated exposures – nevertheless, the dosage rates used appear to be safe for single exposure of livestock or people. The hazard directly under the spray plane is therefore tolerable. The hazard from drift is substantially less. It is not uncommon to receive unfounded reports of damage from spray applications. There have been other reports, some proved, of damage from systemic weed control materials which were wind-carried several miles from the point of release. There also have been verified reports of industrial pollution. But such applications differ substantially from those used in mosquito control in that the mosquito control operations have been safeguarded by limiting the amount of pesticides applied to that which is tolerable. I do not believe that unfortunate accidents which occur should limit our interest in low volume spraying, but we can learn from such incidents what precautions to take so that they may not be repeated. Now I should like to show some slides to illustrate the following significant points:

Improved spray technology has permitted lowering the volume of spray applied for the control of mosquito larvae from 50 gallons per acre in 1935 to 5 gallons per acre in 1945, to 1 gallon per acre in 1955, to about 8 ounces in 1965. Some success has been attained with as little as 1½ fluid ounces per acre, using undiluted insecticide concentrate.

In early tests (1965), a simple spray device was used on a Piper "PA 18" aircraft owned by Kings MAD. This was equipped with a 20-foot boom having only 4 flat fan nozzles and an 8-gallon supply tank, the latter located in the rear seat space. This simple equipment was used in larviciding 35,000 acres in one season at an application rate of 6 fluid ounces per acre, as a practical field test of low volume spraying. The spray from the plane gave good distribution, averaging 4-10 drops per square inch as observed on aluminum foil spread on the ground under the aircraft flight path.

These practical field trials followed earlier small scale tests carried out in 1964 with an old model "Call Air" plane provided by the Tulare MAD for low volume tests. The plane was equipped with a 12-volt electric motor drive pump and 6-11 flat fan nozzles.

In some tests, the spray material was marked with a fluorescent dye tracer so that very small droplets could be detected on magnesium oxide coated plates. The large droplets (20 microns diameter and larger, up to 500 microns) make holes through the coating, smaller ones may leave pits or depressions in the coating, and the smallest ones (less than 5 microns diameter) make no visible disturbance of the coating but can be detected by viewing with a microscope by ultraviolet light which causes the fluorescent marker to glow brightly.

A "Bell" helicopter used on the cooperative low volume larviciding tests at Colusa in 1967, as reported in the Fall, 1968 number of "Down to Earth", used 4 rotary atomizers to produce small spray droplets. This equipment achieved a successful 250-foot wide swath when flown at low levels. The pattern produced by the helicopter was somewhat unusual. The spray from the nozzles toward one end of the boom was deflected sharply downward, and from the other end of the boom, the spray appeared to be deflected somewhat upward before settling to the ground. Since this equipment produced very small droplets (M.M.D. under 100 microns), a considerable portion of the spray material was carried out of the target area, and only about 10% of the applied material could be recovered from assessment plates located in the target area; however, the Dursban® applied was very effective against the mosquito larvae and gave satisfactory control.

A Piper "Pawnee" aircraft was used in the same series of tests, alternately with two rotary atomizers or 4 flat fan nozzles, and this equipment produced satisfactory swaths 125 feet wide. Approximately 25% of the applied material was recovered from assessment plates. It is apparent that the use of very small droplets permits one to obtain wide spray swaths, but at the expense of considerable loss of spray material, which is presumed to drift out of the target area.

In cooperative "HI–LO" tests made in Kern County in 1967 and early 1968, low volume applications were made from altitudes of 1000 and 2000 feet, using spray mixtures of low volatility. Although these were low volume tests, the aircraft were required to dispense insecticide at a rapid rate (more than 20 gpm).

The HI–LO tests were based upon a chart developed to show the theoretical paths of spray droplets of several sizes, if released from an aircraft flying at 1000 feet altitude, with a wind moving in a horizontal path with no turbulence and no variations in velocity (a condition which never exists in nature). From this chart it was evident that droplets smaller than 50 microns diameter fall so slowly due to gravity that they will be carried a long distance in a horizontal direction before coming down to the earth, and are affected generally much more by the air currents through which they fall than by gravity. Larger droplets, up to 300 microns diameter or larger, fall much more rapidly and in a more predictable pattern. Therefore, for HI–LO spray applications, it appears necessary to compromise, between the smaller droplets which may give more efficient use of the insecticide applied, and the larger droplets which tend to be wasteful of insecticide but which can be expected to fall in the target zone. It also appears that substantially larger droplets can be employed efficiently for larviciding where the object is to get the insecticide into the water where the mosquitoes develop, and that smaller droplets should be used for adulticiding where the object is to have the droplets remain airborne for a longer period of time so that air currents may transport them to the locations where the adult mosquitoes may be. Aerosol machines characteristically produce small droplets (5 to 50 microns diameter range) and spectacular results can sometimes be obtained when favorable meterological conditions prevail; however, such conditions rarely continue for long periods of time in the Central Valley of California during the mosquito season, thereby limiting the utility of aerosol machines.

In the cooperative "HI–LO" tests, application rates of more than 20 gal/minute were required to cover the very wide swath which was obtained (up to 10,000 feet). A dual spray system with more than 100 flat fan nozzles was used on the Kern MAD Piper "Pawnee 235" aircraft. The application rate was less than 3 oz/acre.

With the plane flying at an altitude of 1000 feet Rhodamine "B" red dye in the spray made a distinct pattern on the finish of a white car, which was about 1000 feet downwind of the flight path, with about 2-4 droplets/square inch. The polish on the car was apparently a very good spreading agent for the spray material because the droplets spread to make spots more than 1/8" in diameter.

Farther downwind, at 1200 feet, there were more droplets collected on an aluminum pan. These were all large droplets (200-300 microns diameter) and they were quite evenly sized. Still farther downwind at 1600 feet there were greater numbers of droplets, all substantially smaller. At 1800 feet downwind there were even more droplets, of still smaller size.

On one early morning in Madera County, I noted a striking visual representation of the kind of inversions which affect aerial spraying. There was no detectable wind at ground level and 3 fires burning brush from a fig orchard produced dense columns of smoke. The warm air was causing the smoke to rise in a vertical column up to about 300 – 400 feet above the ground, where a horizontal wind was blowing perhaps 1 to 2 miles an hour, cutting off the tops of the columns of smoke. In this instance, measuring the wind velocities at the ground would not permit one to predict where spray material would go if it were released above the inversion. This illustrates the point so often emphasized: we must know what air currents occur when sprays are applied by air.

In the application of low volume sprays, it is important to differentiate between adulticiding and larviciding. On a somewhat arbitrary basis, the following specifications have been developed for use as a guide for aircraft applications – but I freely acknowledge that with the equipment available to us, it may not be practicable to accurately meet these specifications, and furthermore, the need for more fundamental research is acute, for although we can now effectively use low volume spraying, it is apparent that great improvements are possible.

Specifications

"For adulticiding, the objective is to produce and maintain a constant spray output (plus or minus 10% of the required volume output per minute) of any application rate per acre as specified by the State from 2.0 to 4.0 fluid ounces per acre. The droplets comprising the spectrum of spray discharged from the helicopter should have a mass median diameter of 50 to 75 microns. No more than 20% of the volume of sprayed liquid should be in droplets having a diameter greater than 125 microns, as determined by readings made of microscope slides coated with Dri-fil, or by other standard droplet measurement methods."

"The spray operations should produce a distribution yielding a consistent average of at least ten (10) droplets per square inch, as determined by count of spray particles impinged upon recovery cards placed in the target area. The pesticide will be dispensed from an altitude of from 10 to 400 feet above ground, as specified in the field by the State. The representative of the State may specify the number and the size of flat fan spray nozzles to be used.

"For larviciding, the objective is to produce and maintain a constant spray output (plus or minus 10% of the required volume output per minute) of any application rate per acre as specified by the State from 3 to 8 fluid ounces per acre. The spectrum of spray droplets discharged from the helicopters shall have a mass medium diameter of 100 to 200 microns. No more than 20% of the volume of sprayed liquid shall be in droplets having a diameter less than 50 microns, and no more than 10% of the volume of sprayed liquid shall be in droplets having a diameter greater than 300 microns, as determined by readings made of glass plates coated with magnesium oxide or by other standard spray droplet measurement methods.

"The spray operation should produce a distribution yielding a consistent average of at least five (5) droplets per square inch, as determined by count of spray particles impinging upon recovery test cards placed in the target area. The pesticide will be dispensed from an altitude of from 10 to 400 feet above ground, as specified in the field by the State. The representative of the State may specify the number and the size of flat fan spray nozzles to be used."

1968 FIELD TRIALS OF LOW VOLUME SPRAY APPLICATIONS

Eugene E. Kauffman

Manager, Sutter-Yuba Mosquito Abatement District

The low volume technique of aerial spraying was used in 1968 by the Colusa Mosquito Abatement District and by the Sutter-Yuba Mosquito Abatement District.

High populations of *Anopheles freeborni* mosquitoes periodically occur in the town of Colusa as the result of invasions from the rice fields in the vicinity. Therefore, a plan was prepared for a test of the "HI–LO" method of low volume spraying, similar to the trials which had been conducted in Kern County in 1967 and 1968, combined with "vertical stacking", to determine the efficacy of this method in freeing a town of adult mosquitoes. A corollary objective was that of determining whether the method would give good distribution of the insecticide throughout a small town.

The aircraft used was a Piper "Pawnee 150", with 4 nozzles on a short spray boom mounted just forward of the tail wheel. The spray deposit in the target area was assessed by means of potassium-iodide and Kromecote cards, glass slides, mylar sheets, suction air samplers and caged adult mosquitoes. These were located at pre-selected assessment stations along a line perpendicular to the flight path of the aircraft.

The first flight was planned for July 31 but had to be aborted due to insufficient wind. On August 1, the wind velocity was adequate and the test commenced. The plan called for one pass at an altitude of 500 feet, two at 1,000 feet, and four at 2,000 feet, all passes "vertically stacked" above a flight path at the upwind edge of the town. Two passes were made according to plan, but on the second pass at 1,000 feet, the pilot noticed that no material was coming from the nozzles. However, all seven planned passes were made in order to determine the time required for the entire application. The test was evaluated at the end of one hour. Spray droplets were recovered from the line of flight at least two miles downwind, and mosquitoes died in all cages. Observations by local residents indicated there was a noticeable reduction in mosquitoes.

The second flight test was made in accordance with the same plan except that the line of assessment stations was extended to three miles. The application was completed according to plan with all nozzles functioning. Again the droplets reached all of the stations. The station at three miles had many droplets and all the mosquitoes died within four hours.

In the tests, the greatest numbers of droplets were recovered from the farthest downwind test stations, indicating that spray material was going beyond the end of the test line. This gave rise to the question: "How far did the material drift?" Therefore, a single pass was made to determine the drift from a given altitude. A 3,600 feet assessment line was laid out, with potassium-iodide cards at 100 feet intervals. The flight was made at an altitude of 250 feet, across a wind of 4-5 miles per hour. After observing the deposit on the test cards, it was assumed that a town one mile wide could be treated by observing the following swath width-flight altitude-wind speed relationship:

Wind		Make Flights At Altitudes		
1. 2 mph	=	500	1,000	2,000 feet
2. 2 mph	=	250	500	1,000 feet
3. 4 mph	=	125	250	500 feet
4. 8 mph	=	60	125	250 feet

A third application was made to test this assumption. The wind was 2 miles per hour, therefore the 250-500-1000 feet schedule was used. Recovery cards were put out in the town and at 2½ and 5 miles downwind. Examination of the cards showed that the droplet recovery was greatly increased over the two previous tests. Counts of the cards from the first two runs averaged 4.4 and 5.3 drops per square inch, and from the last run, 26.7. Evidently the third application was much more effective than the others.

Caged adults were not used in the last test. Resting stations and light traps were observed before the flight, but a strong north wind following the test rendered a post-flight check invalid.

Two tests were performed in the Sutter-Yuba Mosquito Abatement District against a field population of first to third instar larvae, using Dursban® applied by the ULV technique.

One flight was completed under difficult circumstances. The wind was variable, 3-7 miles per hour, the temperature 90°F and one of the four nozzles was discharging less than its rated capacity. The application was made as part of a project on residue studies. The field of 80 acres was inside a 1500 acre area that gave counts of 10-20 mosquitoes per leg.

The field was treated with a Grumman "Ag Cat" aircraft and conventional spray equipment, flying 100 foot swaths. After the tests less than one larva per fifty dips could be found, compared to pre-flight counts of two per dip.

1968 FIELD EXPERIENCE WITH LOW VOLUME APPLICATION IN THE SAN JOAQUIN VALLEY

Arthur F. Geib

Kern Mosquito Abatement District, Bakersfield

For the past two decades aerial application of pesticides for control of mosquitoes has probably been the most important activity performed by most mosquito abatement districts of the Central Valley. Without planes and suitable pesticides it seems unlikely that adequate levels of mosquito control could have been accomplished within practical economic limits of many valley districts.

During this period thousands of acres have been sprayed annually by applying aqueous solutions at rates of ½ to 2 gallons per acre.

Experimenting in 1962 the United States Department of Agriculture developed interesting and encouraging results with the aerial application of pesticide concentrates in very low volumes - ounces per acre. Starting in 1963 Thomas D. Mulhern of the Bureau of Vector Control, California State Department of Public Health, cooperated with several valley districts in testing this technique for controlling mosquitoes in California. Results were encouraging and further studies of the ultra low volume (ULV) technique have been continued annually through 1968. In the San Joaquin Valley there are 15 active mosquito abatement districts. Ten of these own and operate their own aircraft. During 1968, 6 had ULV spray systems on 9 separate airplanes and 4 utilized ULV for 18 to 100% of their spray programs.

The Kern Mosquito Abatement District began limited ULV operations in 1966. Since that time Kern has annually increased the use of this method of application to a level where practically all aerial spraying was ULV in 1968.

The Kings Mosquito Abatement District began ULV operations in 1967. During 1968 18% of their aerial operations were ULV. The Consolidated District began ULV operations in 1968 and their aerial spray program for the year was 100% ULV. The Tulare District also began ULV operations in 1968 which accounted for 50% of their aerial spray program.

Two different systems are being used by these districts: (1) the pressurized system where CO_2 or pressurized air is being used as the propellant force to discharge the spray; (2) electrically driven pumps, the latter being most common.

All systems use flat-fan or cone-spray nozzles mounted on booms. Small orifices ranging from 800067 to 8002 are utilized to obtain small droplets within a limited size range. Operating pressures normally range from 20 to 40 psi, while discharging a volume of 1.33 to 8 ounces per acre. Two of the districts currently operational with ULV apply swath widths of 100 feet; one at 132 feet and one at 220 feet.

All districts use fenthion for their standard ULV applications. Three of the four dilute or extend the 7 or 8 lbs. concentrate with oils so that they will apply a volume of 3-2/3 to 4 ounces per acre at 0.1 lb. fenthion per acre. The fourth district applies straight concentrate at 1-1/3 to 1.56 ounces per acre.

Malathion is also used to some extent. This is applied at 5 to 8 ounces per acre to obtain a dosage rate of 0.4 to 0.5 lb. per acre.

Four districts have dual spray systems on six aircraft. The Kings and Kern districts utilize these dual systems operationally. They obviously afford maximum flexibility in choice of pesticides and rates of application and thereby increase efficiency.

All districts using ULV report results to be equal to those obtained when using aqueous sprays. All also report they anticipate continuing the use of ULV during 1969 and four additional districts are considering the operational use of ULV during 1969,

Two factors associated with ULV aerial spraying account primarily for the marked increase in spraying efficiency: (1) When applying at only a few ounces per acre a very minimal time is consumed in loading which in turn reduces ferrying time. Very often one or two loads per day is all that will be needed; (2) Swath width increase of swath to double and triple that attained with aqueous sprays really reduces flight time. The Tulare District reports a 50% increase in efficiency and the Kern a 70% increase.

As mentioned previously two districts are operational with dual systems. One of these, the Kern, not only has dual systems on two aircraft it has one plane with three separate spray systems. Two of these are operated with electrically driven pumps and the third is an air-pressure system primarily for the application of Dibrom for adulticiding purposes.

SWATH KILLS OF ONE TO TWO MILES UTILIZING A NEW LOW VOLUME AEROSOL GROUND DISPERSAL UNIT

George S. Stains
United States Navy

Alameda Naval Air Station, Alameda

ABSTRACT

The Navy's new low volume aerosol generator ground dispersal unit has been field evaluated and found highly ef-

fective in the control of mosquitoes and flies. Low volumes of high concentrate Dibrom®, Dursban® and malathion were dispersed in 10-micron mass median diameter size droplets through four double air-liquid vortical type nozzles. These droplets were carried by prevailing winds to test sites various distances up to 12,000 feet from the aerosol generator where they contacted caged adult mosquitoes and house flies. Up to 100% kill was obtained two miles from the point of insecticide release. The rate of flow for each insecticide was calibrated in ounces per minute with the generator traveling at 440 feet per minute.

The aerosol generator was developed specifically for the purpose of dispensing concentrated or technical grade insecticides. Stainless steel plumbing throughout and teflon-lined hoses prevent degradation by caustic chemicals. The pressurized spray reservoir, high volume air blower, double air-liquid vortical nozzles, and 312 pounds gross weight are unique features designed to permit ease of operation, small droplet production, and handling by two men. The pivotal boom allows dispersal in any of the four directions relevant to the generator.

Small droplet dispersal has been found to improve control efficiency, reduce ecosystem contamination, and lower pesticide costs. Theoretically, complete control of mosquitoes and flies over a large area costs only a few cents per acre using this machine. In terms of volume, one droplet 100 microns in diameter is equivalent to a thousand droplets 10 microns in diameter. The probability of at least a few of the 10-micron droplets contacting the target insect is much greater than that of a single 100-micron droplet. In the first two tests performed, 98% of the droplets were 15 microns or less in diameter with over 70% falling under 10 microns.

A new fluorescent particle (FP) spray tracer technique was employed in these studies. This method consisted of suspending a known concentration of FP's in the concentrate insecticide and subsequently analyzing the airborne aerosol cloud with specialized rotor rod sampling devices. The number of FP's in each impact pattern is a measure of the original droplet volume. Hence, total mass, size and distribution of aerosol droplets can be determined. The sensitivity and ease of assessment attainable by this technique make it particularly useful in field testing of insecticide dispersal equipment and in determining the effectiveness of dispersal operations.

PROCEDURES WHICH MAY BE EMPLOYED BY A MOSQUITO CONTROL AGENCY IN ASSESSING LOW VOLUME APPLICATIONS

Don J. Womeldorf and Patricia A. Gillies

California State Department of Public Health
Sacramento, Fresno

Introduction

Operational mosquito control programs using low volume (LV) insecticide applications need to have available quick and easy means of evaluating the treatments. The methods need not reach the degree of sophistication required in highly refined research programs, but should provide basic information as to what is happening during treatment. This paper discusses some of the methods available for calibrating and evaluating LV applications. Many of these procedures have been developed in California mosquito control programs.

Three separate areas are considered: calibration of low volume application equipment, evaluation of depositions of insecticide for larvicidal effect, and evaluation of insecticide application for adult mosquito control. For simplicity, discussions are limited to aerial applications, but the procedures are usually directly applicable to ground equipment use as well.

Calibration

Calibration takes into account the aircraft's speed, the swath width, and the application rate. California's mosquito control pilots are well acquainted with the techniques used to determine aircraft speed (usually by timing flight over measured distances, often using mile-apart roads as markers). Swath width determination is discussed later in this report. Given aircraft speed, swath width, and a desired application rate, the necessary flow rate can be determined according to the formula:

$$\text{flow rate (fl oz/min)} = \frac{\text{swath width (ft)} \times \text{speed (mph)} \times \text{application rate (fl oz/acre)}}{493.86}$$

since:

flow rate (fl oz/min) = application rate (fl oz/acre) x acres/min.

and:

$$\text{acres/min} = \frac{\text{swath width (ft)} \times \text{speed (mph)}}{493.86}$$

Flow rates can be estimated from catalog data but must be checked using the particular LV mixture, since their viscosities are usually very different from water, on which catalog data are almost always based. In most cases, it is relatively easy to measure the flow rate by catching the fluid for a timed period. If the aircraft is equipped with a pressurized system or an electric pump system, the recovery can be made on the ground. Plastic baby bottles are convenient, since they are calibrated in fl oz (Geib et al. 1967). Plastic bags or jugs can also be used. If the aircraft must be in the air to operate the pump system, the problem is more complex, but plastic jugs or bags can be wired or taped to each nozzle to collect the material.

Flowmeters, which provide a running check on flow rates that cannot be obtained in any other way, are available in several models and styles. The cost of these units is not excessive.

The final check on calibration should always be made under operational conditions and should be repeated at intervals as work is performed. The easiest and best method is to measure the amount of material actually applied to a field of known size by, for example, placing a known quantity of chemical in the tank prior to treatment and measuring the amount left after treatment. The difference is the amount applied.

Evaluating Larvicide Applications

Larvicide applications, as the term implies, are limited to treating water. Evaluation, therefore, can be performed by observing the deposition of the material. The surface on which the deposition is made depends upon the nature of the chemical and the purpose for which the recovery is made.

Water-mixed sprays can be applied directly to water-sensitive paper (e.g., Kodak Linagraph® No 809 photographic paper, Eastman Kodak Co., Rochester, N.Y.), a paper which is "developed" by contact with water so that water spots appear as contrasting color and intensity (T.D. Mulhern, personal communication). As an alternative water-soluble dyes can be added to the spray tank and applied to paper cards, sheets, or strips. Some of the dyes have the added advantage of being fluorescent. Ultraviolet light observation often discloses the presence of small droplets not seen under ordinary illumination. An especially intense dye is Rhodamine B Extra (E.I. du Pont de Nemours & Co., Inc. Wilmington, Del.) which provides a good trace when used at the rate of 1 gm per gallon of mixed spray.

For visual analysis, the type of paper is not critical. Index cards can be attached to small wooden or composition blocks with rubber bands to hold them in place, spaced across the expected swath. Adding machine tapes or butcher paper rolls weighted with sandbags, rocks, or anything else provide adequate recovery surfaces. A particularly hard finished paper is sold as Kromekote® (Champion Paper & Fiber Co., Hamilton, Ohio.

Oil-mixed or concentrate sprays can be recovered directly on glass or metal surfaces. Aluminum pie tins provide cheap recovery surfaces and have the advantage of stacking without smearing the liquid. If placed upside down on the ground, little weight is needed to keep them from blowing away. Petri dishes are easily handled glass surfaces. Aluminum foil, microscope slides, or lantern slides may be useful. The oil may be made more readily visible on any impervious surface by dusting it with an oil-soluble dye, such as Sudan Black B (Fisher Scientific Co.) (Blinn and Lovell 1965).

Oil-sensitized cards can be prepared as described by Davis and Elliott (1953). Hard finish paper is dipped into a solution of 1 gm du Pont oil red dye in 200 ml acetone. The cards are dried prior to use. When sprayed, the oil droplets appear as pink spots outlined by a dark red ring.

As an alternative, oil-soluble dyes can be added directly to the spray mix and caught on paper, as with water-mixed sprays. Sudan III (du Pont) gives a good visual response. Fluorol F7GA (Keystone-Ingham Corp., Downey, Calif.) is easily visible in ordinary light and also fluoresces brilliantly. Both are adequate at the rate of 1 gm per gallon of mixed spray. Again, the type of paper is not critical. Any relatively hard finish paper will do.

Certain insecticides lend themselves to recovery with chemicals with which they react specifically. Dibrom®, for example, can be caught on paper cards treated with potassium iodide. The bromine portion of the Dibrom molecule forms potassium bromide in a replacement reaction, resulting in a dark spot on the paper. The cards may be prepared as follows (A.C. White, personal communication): Dissolve potassium iodide in methanol to saturation. Soak standard 3x5 inch index cards in the solution for at least 30 minutes. The cards are now ready for use. Avoid over exposure since the cards darken in the presence of light.

In general, evaluation of larvicidal depositions by visual indicator means had best be limited to subjective analysis. Gross indications of swath patterns can be obtained and effective swath widths can be estimated. Several of the visual pattern techniques can be used to measure droplet sizes by determining the diameter of the spot produced and multiplying by a known spread factor, but these methods are at best of questionable accuracy. As a rule, with the present state of knowledge, it seems most advisable to consider that droplet size determination is beyond the scope of simple field technique.

Quanitation by bioassay (Gillies et al. 1968) is within the capabilities of local agency resources. The method described is based on comparing the mortality rate of mosquito larvae exposed to water containing unknown insecticide amounts with the larval mortality rate when exposed to water containing known amounts. A simplification of the technique can be used to gain an idea of the relative quanities within the swath without determining absolute amounts. Cups containing equal amounts of water and equal numbers of mosquito larvae are placed at measured intervals across the anticipated swath. The insecticide is applied, following which the cups are checked for larval mortality at intervals such as 30, 45, 60, 80, 120, and 240 minutes. If over half the larvae are dead in a cup at an inspection, that fact is noted and the cup is not further observed. This technique readily shows high and low points within the swath and can be used to give more meaning to a visual indicator method.

Recovery stations should be spaced so that at least 20 or 25 units are included across the expected swath. As a rule the recovery line should be at least twice as long as the expected swath width.

Regardless of what technique is used to obtain preliminary estimates of the performance of a piece of application equipment, the final test should be based on field observations under actual control conditions. There is no substitute for careful analysis of the effect of treating mosquito populations in the field. This should be based on thorough pretreatment inspection of the populations; observation during treatment of extrinsic factors such as wind and temperature, with visual indicator analyses or bioassay incorporated into the field application; and careful post-treatment inspection of the population.

Elementary meterological data can be obtained with a Dwyer Windmeter (F.W. Dwyer Mfg. Co., Michigan City, Ind.), a hand-held air flowmeter selling for less than $10, and a sling psychrometer such as a small plastic unit manufactured by Bacharach (Pittsburgh, Pa.) which provides wet- and dry-bulb readings and sells for under $15.

Evaluating Adulticide Applications

Applications of adulticides may or may not involve depositing the insecticide on a surface. If the application is to result in a contact residual, or in an impact and fumigation effect, then a deposit is wanted. Such applications can be evaluated by visual indicator means as described above.

If, on the other hand, the application is to result in an aerosol effect, then measuring deposit may be highly inaccurate, since deposit may only reflect the amount of insecticide that falls out in droplets too large to do an efficient job of killing adults. An air sampling technique is necessary.

The most practical air sampler readily available to mosquito control agencies is caged adult mosquitoes. Cages may be simple wire screen tubes, fitted with caps (Rogers et al. 1957) or closed by folding over the ends and stapling them (W.E. Hazeltine, personal communication). More elaborate cages can be constructed from pairs of wire screen tea strainers hinged like clamshells (C.H. Schaefer, personal communication). Ten to 20 adult mosquitoes are transferred by aspirator into the screen cages from a large holding cage, or the cages may be placed over cupped pupae so that the adults emerge into the cages. Following treatment it may be necessary to transfer the mosquitoes into clean holding cages if there is concern about the residual effect of insecticide deposited on the screens. The adults are observed at time intervals after application and comparative mortality recorded. Additional cages should always be placed well outside the test area to serve as a check.

Droplet size data cannot, of course, be obtained by this method. Quantitation is not feasible except in relative terms. Indications, and only indications, of potential swath width can be gained because adulticiding operations are so strongly dependent upon atmospheric conditions.

As is the case with larvicidal applications, the definitive answer on evaluation must come from the field. Biting counts, resting station counts, light trap counts, or even service request counts may be useful. Results in a target area should, whenever possible, be compared with counts made in a similar untreated area. If practical, deposition analyses or bioassay with caged adults should be included in field evaluations.

References Cited

Blinn, R.C., and J.B. Lovell. 1965. A technique for observing the spray pattern of malathion and other organic phosphate insecticides using spray-deposit assessment cards. J. Econ. Entomol. 58(6):1159-1160.

Davis, J.M., and K.R. Elliott. 1953. A rapid method for estimating aerial spray deposits. J. Econ. Entomol. 46(4):696-698.

Geib, A.F., R.H. DeWitt, and A.C. White. 1967. Ultra low volume aerial application of naled to control adult mosquitoes in California pastures. Calif. Vector Views 14(11):70-73.

Gillies, P.A., D.J. Womeldorf, and J.D. Walsh. 1968. A bioassay method for measuring mosquito larvicide depositions. Mosquito News 28(3):415-421.

Rogers, A.J., E.J. Beidler, and C.B. Rathburn, Jr. 1957. A cage test for evaluating mosquito adulticides under field conditions. Mosquito News 17(3):194-198.

PRESIDENTIAL MESSAGE

James St. Germaine, President

California Mosquito Control Association

I am deeply honored and sincerely grateful to the membership of the California Mosquito Control Association for the faith they have invested in selecting me as their President for the forthcoming year. I hope to be able to serve the Association in as distinguished a manner as my predecessor, Past President James W. Bristow. I shall rely heavily on his advice during my term of office.

While serving as your President, there are three major areas with which I shall be most concerned. I shall to the best of my ability augment the outstanding efforts already being made to acquire funds for research. Two, I am particularly concerned with the impoverished districts in our state and their dire need for more adequate funding. I shall seek for them solid support from this organization to better implement their individual programs. Three, I shall try to impress upon those districts which are adequately staffed, equipped and funded, the very real need for widening their vector control activities.

We should be the leaders in all aspects of arthropod control in our various communities. If, for one reason or another, we cannot provide operational control of arthropods other than mosquitoes, we shall let the public know that we can and will serve them in at least an advisory capacity. In short, I am suggesting that we, as members of the CMCA, meet the needs of vector control in this state.

With the guidance and advice of the Bureau of Vector Control and Solid Waste Management and the University of California and other interested agencies, I firmly believe we can achieve this goal.