PROCEEDINGS AND PAPERS

of the

Thirty-Eighth Annual Conference of the

California Mosquito Control Association, Inc.

held at the

SACRAMENTO INN

SACRAMENTO, CALIFORNIA

JANUARY 26-28, 1970

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 – September 25, 1970

CMCA Press – Visalia, California 93277

TABLE OF CONTENTS

1970 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.

AMERICAN CYANAMID COMPANY	Franklin Allen, District Manager A. O. Jensen, Technical Coordinator	2150 Franklin Street Oakland, California 94612
CHEMAGRO CORPORATION	G. C. Bryars, Regional Sales Manager	1400 North Harbor Blvd., Suite 228 Fullerton, California 92632
CONTROLLED AIRSTREAMS	Roy McBride, President	P.O. Box 1242 Gardena, California 90249
CURTIS DYNA PRODUCTS		P.O. Box 297 Westfield, Indiana 46074
DOW CHEMICAL COMPANY	Al Nilsen, Product Sales Manager	Midland, Michigan 48640
	Harold Lembright, Agriculturist	350 Sansome Street San Francisco, California 94106
DURHAM CHEMICAL COMPANY	Jack Prieur, Sales Manager	4124 East Pacific Way Los Angeles, California 90023
PACIFIC ENZYMES	Gordon J. Boersma	P.O. Box 6183 Sacramento, California 95860
J. HAROLD MITCHELL COMPANY		305 Agostino Road San Gabriel, California 94176
HUGHES HELICOPTERS	Richard Turley, Regional Sales Manager	3129 Kermath Drive San Jose, California 95132
HUMBLE OIL COMPANY	R. C. Fraser, Sales	1800 Avenue of the Stars Los Angeles, California 90067
INTERNATIONAL HARVESTER		2855 Cypress Street Oakland, California 94608
KAISER JEEP SALES CORPORATION		185 Valley Crive Brisbane, California 94005
MANITOU EQUIPMENT COMPANY	F. G. Beukers, Sales Representative	P.O. Box 1236 Redwood City, California 94064
McKESSON CHEMICAL COMPANY	Roy H. Overbey, Branch Manager	P.O. Box 2647 Fresno, California 93745
MOYER CHEMICAL COMPANY	Kenneth D. Gillies, Vice President	P.O. Box 945 San Jose, California 95108
OCCIDENTAL CHEMICAL COMPANY	Marvin Schreck, Technical Sales	P.O. Box 198 Lathrop, California 95330
WILBUR ELLIS COMPANY	Ivan Smith, Technical Sales	P.O. Box 1286 Fresno, California 93715

Omissions from Table of Contents

Bert E. Geisreiter

E. Henry Kloss

Robert T. Monagan

John J. McFall

Louis F. Saylor, M. D.

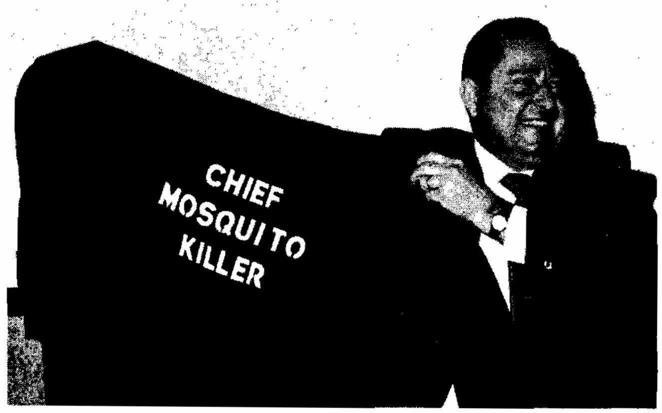
John W. Kilpatrick

John R. Teerink

William C. Reeves, Ph. D.

Telford H. Work, M. D.

James St. Germaine Kenneth G. Whitesell



Kenneth G. Whitesell

California Mosquito Control Association

CALIFORNIA LEGISLATURE

Robert T. Monagan
Speaker of the Assembly

I am sure that it is easy for all of us to look at our problems and to become pessimistic at the trends we see.

We all face the problem of the general turndown of the economy of California, particularly as it affects running the State government. We are in a very difficult position, and although I do not wish to appear overly pessimistic, we must face facts.

You are interested in certain items in the State budget, such as research projects, and support for various other activities. Projects such as these are always affected by the general economy of the State. This year, funds to pay for these projects are going to be very hard to come by. We are going to face a serious revenue deficit.

For a long time we have been facing the fact that the cost of government increases faster than do the revenues to pay for it. As a result, this year the budget is going to be a very tight document. Anyone seeking additional funds not included in the budget will be faced with a difficult uphill fight.

Another problem with which you are concerned is tax reform. We are talking about tax reform, not tax relief. There is no way of getting tax relief unless we are willing to cut back on government services. I am optimistic that we can enact an acceptable, palatable tax reform program this year that will shift some of the cost of government from property tax to some other taxes.

A year ago the big issue in the Legislature was the matter of campus disturbances. This year we have a new issue before us: the environment. No legislator would dare go back to his electorate at the end of this session unable to tell his people that he had put through some bill dealing with environment and pollution. At the least, he will say that he struggled hard to do something about this difficult question. We already have more than 50 bills in this subject area, and my guess is that several hundred bills dealing with the control of the environment will be introduced this session.

California has not been sitting still on all of this. We have made considerable progress in trying to attack the problem of smog. We have the strongest smog controls of any state in the nation. But we are considering additional legislation to strengthen our controls even more. In the area of water pollution, again we have the strongest laws of any state; last year we passed the Porter-Cologne Bill which provides for fines up to $6,000 per day for those persons who pollute our water sources.

The public is demanding action from the Legislature – and the demand will become louder in the future – to deal with a variety of problems for which there is no ready solution. As you well know, a lot of confusion surrounds how one solves most of the environmental problems. For example, the drilling for oil on our offshore lands creates no little controversy. It has become obvious that those who demand an immediate end to all offshore drilling are not sufficiently conversant with the facts to help us make a decision as to which path we should follow. But it is clear that we should stop some of the drilling. Which to stop is our problem.

One of the greatest contributors to the spoiling of our environment is the population explosion. We like to use our business and industry as whipping boys; we like to call them the chief pollutors of our environment. But in reality people are the principal contributors. As our population explodes, the pollution problems grow, and at an even greater rate than the population. California's population problems are becoming astronomical, as are the population problems of the world in general. With 3.8 billion people now in the world, 7 billion expected by the year 2000, and 14 billion by the year 2035 there simply is no question but that we must find answers to the population explosion. What they are will tax our minds for the rest of this century.

Another question we must answer is this: Are we willing to pay the price to stop the despoiling of our environment? An astronomical amount of money is needed to solve the problems of municipal water treatment, solid waste disposal, parks and open space, and new concepts in transportation. The problem of our cities pouring their wastes into our water resources is one of the most difficult that we face.

Some time ago I suggested that perhaps one way to make a major attack upon our environmental problems was to employ a bond issue, so that we could begin an immediate attack upon these problems, but spread the cost over a number of years. You would be surprised at the number of letters I received from people who said, "Let the people who are causing the problem pay for its correction." Some people have conveniently overlooked the fact that we are the ones who cause pollution, not some mythical "they".

In closing, I hope that you will take the time to call on your Assemblyman and Senator when you are in Sacramento to discuss your problems with them, so that they, in turn, can report to you some of the things to which they are giving consideration. There is a fine, dedicated group of men and women serving you in Sacramento and I know that they would be happy to discuss any problems you have at any time. That's what we're there for. Thank you again for this opportunity to talk to you.

WHAT'S HAPPENING IN WASHINGTON

John J. McFall
Congressman, District 15

There is considerable confusion around the country about the objectives of our society in the world and in this country. Let us hope that in the next session of the 91st Congress we will be able at least to define the issues and to make more progress on them.

We have made progress during the last decade, although it has been obscured by the emotion over the war, the riots in our cities, the inflation. There are twice as many students in our colleges as there were 10 years ago. The number of people below the poverty line has been cut nearly in half, and there is more real income in the hands of the people in spite of inflation. But the problems we face seem to dwarf that progress. This is the way it has always been in America where we are not satisfied with the status quo. Many people, I am sure, do not know there has been a California Mosquito Control Association for 40 years. You are making our environment better, improving it from year to year.

What is happening in Washington? There are several major issues we must face – education, crime, inflation, the war – and, we hope, the making of a peace throughout the world.

Another issue is environment, in which you have been involved for a long time – long before environment and ecology became the popular items they are today. Water pollution is one of the most important factors in environmental improvement, and I believe we shall see progress in our water pollution control legislation. The House already has passed the Water Quality Improvement Act of 1969, which adds more tools with which to work. It provides for the control of water which is very close to our shores, of pollution by ships, and it provides a certain amount of research to determine how we are going to proceed with water pollution expenditures.

You are interested in H.R. 14234, which is the bill agreed upon by the American Mosquito Control Association, called the Mosquito Control Act of 1970. I would like to congratulate AMCA for its work in preparing this legislation. I notice from some of the correspondence given me by Congressman Hale Boggs of New Orleans that some of you have been working on this legislation for about 14 years. It is only in the last two years that the Association has been able to get together with a proposal which may iron out some of the differing opinions "within the industry". The bill provides 50/50 matching funds to states, up to $2,000,000 to any one state. Where states do not have active mosquito control programs, or do not cooperate with local areas in mosquito control operations, funds can be released directly to local mosquito control districts or other local operating agencies. All methods of mosquito control carried out with federal funds would be those methods agreed upon by the U.S. Departments of Interior and Agriculture. Under the Act, the U.S. Public Health Service could receive $1,000,000 per year for three years for administering the overall project. It could utilize the funds for consultant purposes and for carrying out demonstration projects in the states and local areas on methods of control which have been developed recently and which require field testing.

There are three basic points in the bill. One has been the elimination of research and technical studies. There is now a good mechanism for making research grants available to qualified professionals in the state and local agencies. Therefore, there are no funds available for surveying, for defining mosquito problems, or for demonstrations. A second point has been the requirement that any method of mosquito control supported by Federal funds should have the concurrence of the U.S. Departments of Agriculture and Interior. In the past, attempts to obtain Federal aid for mosquito control have been killed by the Department of Interior or state agencies having similar responsibilities. The third point has been the planning whereby Federal funds should flow through agencies of the states set up to handle such funds. However, where no such state agency exists, the U.S. Department of Health, Education and Welfare will be granted the power to make the funds available directly to the qualifying local areas. There has been no action on this bill as yet.

I appreciate the opportunity to meet with you today and am certain an interesting and productive conference lies ahead for all.

CALIFORNIA'S HEALTH PROBLEMS

Louis F. Saylor, Director
California Department of Public Health, Berkeley

A great deal of emphasis has been placed on the Environmental Health and Consumer Protection Program in the Department of Public Health since I became Director. In fact, most of the increases in Department staff and resources during that time have been to bolster this important program.

But there are other aspects of public health – interdependent with environmental factors – that affect our communities. I would like to discuss these briefly because others will talk in more detail about mosquito control, other vectors of disease and the environment generally.

Preventive Medicine

Although a lot of people think we have overcome infectious and communicable diseases, this is unfortunately not so. We have coped with a few but we really do not know much about the workings of others. Encephalitis gave us a real scare last year, although the control program was so successful that we had fewer human and horse cases than usual. A great deal of credit belongs to local mosquito control agencies for this accomplishment.

We still have not been able to eliminate tuberculosis. We know next to nothing about how to control colds and influenza, even though we now know more about the causative agents.

In spite of an all-out effort, we are barely able to control the rising syphilis rate. Gonorrhea is rampant in California. We estimate that in 1969 we had somewhere between 60,000 and 70,000 new cases. That is an epidemic.

Chronic, disabling conditions are everyday problems. We still do not know enough about cancer, heart disease, vascular disease and arthritis. We do not know how to diagnose them ahead of time, we can only guess at who will be afflicted and, except for some advances in emergency treatment, we do not know much about preventing their occurrence. At the moment, your chances of having cancer, heart disease, cardiovascular accident, arthritis and so on are about the same as 1,000 years ago.

Professionals in the dental health field say that if money were no object in California, we would still have less than 25% of the needed personnel and facilities to cope with existing dental problems.

Everyone talks about drugs, about smoking, malnutrition and alcoholism. We consider these social-medical conditions. Why? You don't have to take drugs. Dope is the result of some social problem or pressure; the same is true of smoking. We are completing a fairly intensive study in California to determine just who is malnourished and why. Malnourishment covers a spectrum, from overeating because of compulsion and availability of money to near-starvation because of lack of money. There are other variables, of course, such as poor choice of diet and ignorance of good nutrition.

Environmental Health

In public health we have been trying to interest people in the environmental aspects of better living for a long time. Maybe enough people now are sufficiently excited about environmental hazards to provide the necessary dollars for cleanup and preventive programs. There are certainly more than enough instant experts on the subject. Everyone is an expert on pesticides, or so it appears. Each has a different policy which he wants adopted by government. On DDT, the demands swing from "stop it yesterday" to "don't stop it at all". We do not want to further contaminate the environment or to eliminate birds, nor do we want to increase the DDT content of mothers' milk. Neither do we want to restrict the use of pesticides to the point where food costs are prohibitive. Nor is it sensible in a wholesale fashion to substitute short-lasting, more toxic pesticides that may produce illness and even death among agricultural workers. The Legislature will listen to experts – you, the University people, those in public health, and it will adopt a position that probably will be a compromise.

We lose about 10,000 persons a year from accidents. About half of these accidents occur on the highways. We are conditioned to accidents as a way of life and don't pay much attention to the toll. I wonder what public reaction would be if we lost 5,000 persons from encephalitis, or the same number in an epidemic of influenza?

Accidents are environmental health problems, and are not "accidents". Given a certain combination of driver, weather, automobile and highway, an "accident" is not hard to predict. If you stick your hand in a fan, is that an accident? Not at all. These things are preventable. Some safety features on automobiles, for example, should have been instituted years ago. Highway design is another problem. We know how to control some accidents, yet they continue to be a major health problem because of apathy and resistance to change.

Health Services and Facilities

We do not have the manpower needed to cope with rising health care demands. California has always imported much of its medical manpower. We talk about the possibility of extending the professional's time by the use of assistants, etc. In the last 30 years we have seen creation of a number of new professional health care classifications. This is important because the high cost of training a doctor, dentist or microbiologist comes out of the gross national product. It is uneconomical to spend 10 or 15 years training a man or woman to do something in the health field that someone else can do with a year's training. We have to come to grips with the problem of under-utilizing highly skilled manpower in tasks requiring only a small part of their skills.

In California we have a good supply of health facilities, e.g., acute hospital beds, nursing beds, etc. These facilities become obsolete, however, and must be modernized to meet more exacting standards of patient care. The cost of one hospital in California is between $40,000 and $50,000, depending on the area. Nearly every year our growing population requires additional health facility capacity equal to the needs of a city of 500,000. If a 100-bed hospital is required, for instance, the cost might be $5 million.

We are also concerned about the quality of health care. We want to be sure that patients get care when they need it, and that they obtain the appropriate kind of care – neither too little or too much. It is a problem everyone in the health field is working on and it has not been solved.

The Future

What are the prospects for controlling some of these health problems?

In the area of preventive medicine, vaccines for German measles and mumps have been developed. We are trying to identify the causative organism in hepatitis because we see about 12 times as many cases today as we did 10 years ago. A number of investigators are trying to develop vaccines effective against syphilis and gonorrhea. The role of viruses in formation of cancers is being investigated by us and many others. Convincing some people that putting fluorides in the water – to prevent dental decay – will not poison them is difficult; the fluoridation cost/benefit ratio is something like 1 to 1,000, yet opposition still is great. Apparently we are getting somewhere with smoking; at least fewer young people are buying cigarettes. And in nutrition, we hope to design specific programs that will benefit people who most need assistance, particularly young children.

Hundreds of bills have been introduced in the Legislature to control environmental hazards. There is much that can be done and it will be interesting to see what results. A number of groups in California, especially those engaged in comprehensive health planning, are working on ways to deliver health services in a better and more economical way.

I can summarize by saying that, at the state level, we do not foresee a marked increase in the number of tax dollars available for health purposes. Our approach, therefore, is to re-examine our priorities, to set realistic objectives, and to analyze our programs in terms of costs-benefit effectiveness. We hope to be innovative in the way we use our resources, which is another way of saying we will try "to get the most bang for the buck".

CHALLENGES IN MOSQUITO CONTROL

John W. Kilpatrick
United States Public Health Service
Atlanta, Georgia

Progress in mosquito-borne disease control has been observed for over 60 years. Nevertheless we are constantly reminded of how little we know about the relationship of mosquitoes and disease. Also, individuals in their everyday activities are creating more problems, such as increased use of nondestructible containers, the overtaxing of waste disposal facilities, etc. Industry should not be singled out and chastised from the standpoint of the creation of all of our environmental problems, but rather all of us as citizens should be willing to assume our part of this major responsibility.

Enormous strides have been made in the control of mosquito-borne diseases such as malaria, yellow fever and dengue. Yet on a worldwide basis malaria continues to be one of the most important diseases of man. The World Health Assembly reported in 1967 that, of the 1,692,000,000 persons originally inhabiting malarious areas, 654,000,000 of these now live in zones where eradication has been obtained. There are 674,000,000 who live in regions where eradication programs are in progress, and 364,000,000 in countries where such programs have not yet begun.

It is a formidable accomplishment that more than two-thirds of the population of the originally malarious areas are now living in places that are free of malaria or in places where malaria eradication programs are being carried out. Unfortunately, there is a stalemate in the program in the Americas. Within 3 hours flight of this room, in Central America, is an area that is one of the most difficult for malaria eradication. The problem is complicated by strains of *Anopheles albimanus* which are resistant to insecticides, and by people who live for a considerable portion of their time outside of dwellings. Also, resistance to anti-malarial drugs has been encountered in the last few years. The African region has advanced very little in spite of its having the highest malaria endemicity. Southeast Asia is an area where probably the greatest gains have been made toward eradication.

However, military personnel coming to this country from Vietnam are having increasing incidence of malaria. The figure on malaria cases has risen sharply in the last 5 years, from only 156 cases in 1965 to 2,423 during the first 9 months of 1969. In the last 25 years, with millions of military personnel returning from World War II, the Korean Conflict, the Vietnam Action, and other areas, this country has been fortunate that not more than 58 cases have occurred in people who have never been out of the United States. The largest single outbreak in the United States in recent years, with 35 recorded cases, resulted from one Korean veteran who slept outdoors near a girl's camp in 1952. In the last 15 years there has been no reported transmission in California associated with returning veterans.

Although urban cases of yellow fever have not been reported in recent years, the threat of this disease continues. This year major epidemics of jungle yellow fever occurred in Nigeria. Apparently there were thousands of cases, with numerous deaths. The outbreak occurred in the last couple of months of 1969 and specific figures are not available. Vaccination programs will have to be continued in tropical Africa.

In the Americas great hopes were held that the threat of urban yellow fever might be eliminated completely by the *Aedes aegypti* eradication programs. Much progress was reported year after year. The United States joined this program in 1964 and continued through 1968 at which time the eradication program was terminated. The Pan American Health Organization reported widespread infestations in Mexico, El Salvador, Guatemala, Panama, the Antilles, Venezuela, Columbia, Brazil and the Guineas. So the idea of *Aedes aegypti* eradication has taken a decided setback as it relates to yellow fever transmission. A re-appraisal of yellow fever control will have to be made, including the use of improved techniques, such as the jet injector gun for immunization, better techniques in laboratory identification of the disease, and quarantine measures.

Major epidemics of dengue have occurred in southeast Asia and the Caribbean in recent years, including one with an estimated thousands of cases in Puerto Rico. This occurred primarily in the northern half of the island where *Aedes aegypti* populations were the highest. In southeast Asia Dr. Albert Rudnick of the Hooper Foundation of the University of California studied the possibility that dengue may be a zoonosis, in which the reservoir could be monkeys in jungle areas. Cases of hemorrhagic fever are routinely reported from areas of the Phillippines, Vietnam, Thailand, Malaysia, Singapore, Calcutta and other areas.

Mosquito-borne arboviruses are diseases of increasing significance. For years there was concern only for the three better known viruses – eastern, western, and St. Louis. Then virologists began finding California encephalitis in many parts of this country, and in 1968 and 1969 more cases of this disease were reported than any of the other three. In 1968 the first case of Venezuelan equine encephalitis was reported from a woman living in the Miami area of Florida. At the present time over 200 arboviruses are known. Many of them are simply viruses isolated from mosquitoes without corresponding human or domestic animal association. The future holds a lot of additional information with regards to the disease potentials of many of these viruses.

Filariasis is a disease of the tropics and subtropics, with thousands of cases reported annually. In Rangoon, a larvicidal campaign against *Culex fatigans* has been conducted by the World Health Organization for several years, and a demonstration using two incompatable strains will be started in 1970 in India.

Vector control in the future needs to provide for adequate training of personnel all over the world, plus a backlog of films, literature and the latest information. Since 1940 major emphasis has been placed on the use of pesticides in mosquito control programs. Control programs throughout the world have fallen into the trap of using pesticides in lieu of more diversified program approaches. These comments, by no means, should be construed as running down the need and the desirability of using pesticides for mosquito control. Rather, consideration is needed for a middle-of-the-road approach between the total banning of pesticides and the total disregard for adverse effects which might be derived from their use.

From many standpoints, preventive programs should receive major emphasis, while curative programs should be reduced insofar as possible. Although it cannot be stated for certain what happened to the encephalitis virus picture in California in 1969, California mosquito control workers can take credit for a major effort in keeping *Culex tarsalis* under excellent control in a high water year, and this could have been a major factor in keeping the encephalitis viruses at a low to nonexistent level. This is what is meant by "preventive" vector-borne disease control.

During the past few years the U.S. Public Health Service has worked with states and local areas in vector control programs. Efforts were expended in one area where an epidemic of encephalitis was in full bloom; and it is believed that, using ultra-low volume dispersal of malathion, the cooperative effort was instrumental in changing the pattern of the epidemic. In more recent years the National Communicable Disease Center has recommended this procedure in preventive programs in several areas in Texas, and in Ohio in 1969. Ultra-low volume applications were used both as adulticides and larvicides in preventive programs.

In many areas it has been shown that mosquito predators were very instrumental in reducing mosquito populations. Indiscriminate treatment of large areas, without inspection, may destroy predators and eventually result in higher mosquito populations than if no program had been instituted.

Mosquito control workers are at the threshold of a new era. Whereas in the past insecticides could be applied in almost any manner with satisfactory results, this situation no longer exists. Mosquito control is now a sophisticated science requiring professional entomological and engineering intelligence, in-depth knowledge of the biology, ecology and habits of the important mosquito species, and the development of control programs employing numerous and varied techniques judiciously and intelligently applied.

THE CALIFORNIA WATER STORY

John R. Teerink
Deputy Director – State Department of Water Resources

The history of California is written in the story of its water development. In the early 1900's, California, in coping with its arid environment, began to go great distances for its water supply. Los Angeles went to the Owens Valley to construct the Owens Valley aqueduct. It also joined with other communities in southern California to form a Metropolitan Water District, going to the Colorado River in the early 1930's to bring water through the Colorado River aqueduct to the south coastal plain, with actual delivery beginning in 1941. San Francisco and the East Bay cities went to the Tuolumne and Mokelumne Rivers in the 1930's to import water for their needs.

The State Water Project was conceived in the years following World War II. With the tremendous population growth at this time, it was apparent that the available water supplies in many areas would be far under the water demands. Therefore additional supplies would have to be developed and imported to the deficient areas, principally the San Joaquin Valley, southern California, and the central coastal area. At the same time, in northern California the flood control problems such as the rampaging Feather River spurred the state to move forward with the construction of Oroville Dam. Oroville Dam was not feasible as a single purpose project, since flood control alone could not bear the cost. It was a feasible project when water supply and power development were added to its function.

The State Water Project is about 89% completed or under contract. Some issues and questions are now being raised, such as "Why take more water to Los Angeles in order that they can produce more people, drive more automobiles and produce more smog?"

We who are planning water projects are looking ahead to 1990, 2020, etc. The time it takes to plan, design and construct a large project may be at least 2 decades. The State Water Project was authorized by the Legislature in 1951. The first water will be delivered to southern California in 1971. A project authorized now might not be completed until 1990. There must be planning to determine needs after that time.

Where will the future population expansion in California take place? Should the government control growth and places where people can live? Will California agriculture, with shifting interests, be able to produce its share of food and fiber for the nation? Can more crops be grown on less land and with less water? Is high price water being used to irrigate subsidized crops? What will be the amount of water used by industry in the future? The answers to these issues are not clear, but they must be faced. Studies of the per capita use of water indicate that it is directly proportional to per capita income – when income goes up, water use goes up. There are of course other factors affecting per capita use such as temperature and multiple dwelling density.

An example of a major problem is "Where do we go for power?" The rate of energy use in the nation is increasing much more rapidly than the population increase. Fossil fuels are being consumed at a higher rate than ever before, a fact creating concern by the environmentalists. There is suggested that one of the consequences is a "greenhouse" effect as a result of the burning of the fossil fuel with the production of more and more carbon dioxide into the atmosphere, and the reduction of oxygen. It is believed this will create a long range warming effect.

Fossil fuel steam plants are coming under attack. A contemplated legislative bill would ban all fossil fuel plants in California. Recently Southern California Edison was denied a permit to increase the size of its steam plant. It appears that power plants will move in the direction of nuclear power. A look at the future load growth in California indicates a possible need for nuclear power plants about every 10 miles along the coast line. Southern California Edison recently indicated it was forced to go inland for one-half its future power requirements, and that by the year 2000 it would need one million acre feet of water per year just for cooling purposes. That is the amount which the Metropolitan Water District brings from the Colorado River through its aqueduct.

There is a major concern for future water planning in California. There is a need to discuss water, power and population issues at state and national levels.

Our Department of Water Resources is working with local mosquito abatement districts in problem areas created by our water development program. We are correcting or attempting to alleviate any problems occurring due to changes in land and water development.

We believe that the time will come when part of our water supply will come from desalination of sea water. Possibly this will occur in the south coastal areas about 2000.

Some water reclamation is occurring now in several areas of southern California. Much of the effluent now being produced at waste treatment plants is not suitable for reclamation due to high salinity. Thus much of this water now going into the ocean is not reclaimable. However, communities with high water costs and with increasing waste water treatment plant costs are looking more to reclamation.

CURRENT OBSERVATIONS ON MOSQUITO–BORNE VIRUSES OF CONCERN TO MOSQUITO ABATEMENT DISTRICTS IN CALIFORNIA[1]

William C. Reeves, Ph.D.
School of Public Health, University of California
Berkeley

I appreciate the honor of being asked to summarize the events of the past year concerning the mosquito-borne viruses that are of concern to mosquito abatement agencies in California. In one way this is a simple task as these infections were at the lowest level in 1969 that they have been since we started studies in the early 1940's, thus the topic might deserve little discussion. However, it is a much more difficult task to explain, as I was asked to do, why western equine encephalitis (WEE) and St. Louis encephalitis (SLE) viruses did not reach high levels of activity through a large part of the state in 1969.

[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-SO1-FR 05441 from the National Institutes of Health, U.S. Department of Health, Education, and Welfare.

Preludes to the Summer of 1969

During the winter of 1968-1969, those familiar with the premonitory signs of the environment that precede a bad year for *Culex tarsalis* Coq. and the viruses this mosquito carries had great reason for concern. Rainfall over much of the state and snowpack in the Sierra Nevada rapidly accumulated to the point that prior records for precipitation were broken. It was obvious by early spring that much of the Central Valley and particularly the San Joaquin Valley was going to be flooded and that water releases from snowpack and flood control dams were going to continue through much of the summer. Thousands of acres of land were flooded in the spring. Overwintering female *C. tarsalis* emerged in the early spring and there was an early spring buildup of the vector population. Most mosquito abatement districts started their surveillance for breeding and control operations far before their usual schedules.

Earlier observations in California and other western states have shown a correlation between years of WEE epidemics and unusually low temperatures in the spring. Dr. Hess and his co-workers (1963) found that when 10 day degrees over 70°F occurred late in the spring, this was followed by high levels of WEE viral activity. They recommended that this measure be used as an epidemic predictor. Over the past 15 years the average date for such temperatures to accumulate in Kern County was April 22 and in 1969 it did not occur until April 28. Temperatures continued below normal in the Central Valley into June. Thus, this predictor favored WEE virus activity.

We know that there had been a degree of resurgence of WEE and SLE viruses in the Central Valley in the summer of 1968, and there was every reason to expect a further increase in 1969 if there was a large vector population.

Summer of 1969

By May, we had mounted the largest program to prevent an epidemic of encephalitis in the history of our state. This effort represented a coordinated and joint action of all the concerned agencies in the state as well as the federal government.

Mosquito abatement districts expanded the surveillance for *C. tarsalis* and their control operations to the limit of financial and personnel resources. Control efforts were concentrated on the protection of susceptible people in urban and rural population centers, but also encompassed extensive flooded areas that were some distance from heavily populated areas. We suspected that these more remote areas might be foci for viral buildup in the mosquito vector and wildlife host populations.

The State Department of Public Health mounted an intensive surveillance program to detect clinical cases of encephalitis in man and equines early and rapidly. Their program encompassed constant contact with 54 hospitals and almost all practicing veterinarians in the Central Valley. In addition, the Department initiated a surveillance of mosquito breeding and adult *C. tarsalis* populations in areas of the Central Valley that were outside the boundaries of local control agencies. Veterinarians were urged to intensify vaccination programs. Before summer, a system had been established to report all intelligence data back to local agencies each week.

The Schools of Public Health (Berkeley and Los Angeles) undertook to intensify their surveillance of viral activity in mosquito vectors and sentinel animals in representative areas of the state that included Kern, Butte, Glenn, Inyo, and Imperial Counties. The College of Agricultural Sciences and the State Department of Public Health undertook continued surveillance for pesticide resistance in *C. tarsalis* in areas where control failures were noted.

Finally, a request was made to the National Communicable Disease Center to make periodic collections of mosquitoes for viral tests in areas of the Central Valley that were not covered by the above surveillance programs.

The above description omits many activities and agencies that were involved but indicates the breadth and depth of program that was developed and the mutual concern that allowed such coordinated action. Between $10 million and $11 million were expended in this program and almost all the money was devoted to control.

Findings

Mosquitoes – The Bureau of Vector Control has summarized all the findings on mosquito populations and has distributed these data to each mosquito abatement district. While there was an increase of *C. tarsalis* in some urban areas and rather large populations developed in some uncontrolled or partially controlled regions, the general pattern through the summer was a tribute to the control effort made by the districts. I am confident that the low levels of *C. tarsalis* that prevailed in almost all urban areas of the state were at or below the threshold levels required to develop an epidemic that I reported earlier (Reeves, 1968, 1969).

Viral tests on mosquitoes provided some surprising results. Over 210,000 mosquitoes were tested in the various laboratories and these included 110,000 *C. tarsalis*. The results from my laboratory are presented in Table 1. Turlock virus was isolated a number of times from Kern County but WEE and SLE viruses were not detected. In the Sacramento Valley, SLE virus was isolated in the late summer but WEE and Turlock viruses were not. The State Department of Public Health reported (Emmons and Marlor, 1969) making 13 isolations of SLE virus from the northern area in the late summer period. The National Communicable Disease Center tested 55,136 *C. tarsalis* collected through the summer from both northern and southern parts of the valley and this resulted in 2 isolations each of Turlock and Hart Park viruses and a number of isolations of some new agent that is not WEE or SLE virus and has not been identified (Sudia, 1970). Dr. Telford Work will report in the following paper on this program regarding the isolations of California group viruses from *Aedes* collected in the Owens Valley.

Table 1. *Culex tarsalis* tested and viral isolations, 1969.

Area collected	No. tested	No. viral isolations WEE	SLE	Turlock
Kern County	27,024	0	0	51
Butte-Glenn Counties	14,482	0	12	0

State Health Department reported 13 SLE isolations from *C. tarsalis* collected in Tehama, Shasta, Sutter and Solano Counties.

Clinical cases – The State Department of Public Health has published the results of their intensive surveillance for clinical cases and these are summarized in Table 2 (Emmons and Marlor, 1969). The five human cases of SLE all had onsets in late summer and were exposed in the general northern region of the Central Valley where SLE virus was isolated from *C. tarsalis*. The two proven WEE cases in horses also were from the northern region.

Table 2. Distribution of diagnosed encephalitis cases, California, 1969. (As reported by California State Department of Public Health)

Host	County of residence	No. of cases SLE	WEE
Human	Sutter	1	
	Sacramento	2*	
	Glenn	2	
Horse**	Tehama		1
	San Joaquin		1

*1 resident of Alameda County, probable exposure Sacramento County.

**5 horse cases suspect WEE because of high stationary antibody titers: 1 Glenn County, 2 Fresno County, 1 Kern County, 1 Sonoma County.

Sentinel chickens – We had numerous flocks of sentinel chickens that were exposed to mosquito attack throughout the summer. The results of serologic tests on blood samples collected at the end of the summer (Table 3) were what we had expected from the distribution of viral isolations from mosquitoes and clinical cases. Turlock virus was active in Kern County. SLE, WEE, and Turlock viruses all were active but at low levels in the Sacramento Valley.

Table 3. Serologic tests on sentinel chickens exposed entire summer of 1969.

Area exposed	No. chicks	Percent positive HAI tests WEE	SLE	Calif.	Turlock
Kern County	199	0	0	0	5
Butte-Glenn Counties	188	0.5	11.2	0	0.5

Other western coastal states – It was of some concern to us that WEE virus produced epidemics of encephalitis in horses in eastern Oregon and Washington this past summer. We kept expecting a similar development in at least the most northern areas of California where there was minimal or no control but this did not occur.

Explanations

I do not have a definitive answer to the question, "Why did mosquito-borne viruses remain at a low level of activity in 1969?" However, I would like to discuss briefly variables that we might expect favored viral activity and some that may have suppressed activity.

We have reason to believe that the epidemic predictor of excess water is still valid. We know it will be reflected in increased *C. tarsalis* breeding if it is not carefully managed, kept under surveillance, and controlled when necessary. The unusual level of effort and in most cases effective control program of last summer would have suppressed viral activity over a large area. Unfortunately, we cannot say that we stopped viral transmission as there were rural localities where there was less intensive or no control. At such localities, there was also little or no viral activity and there were large populations of *C. tarsalis*.

The increased vaccination of horses that followed the early warning of an epidemic potential undoubtedly converted many animals to an unsusceptible status. I suspect that we would have had more horse cases and a better idea of specific localities where WEE virus was active in the absence of vaccination. However, it is obvious why this was not desirable.

I must confess that I do not have an explanation for the failure of WEE virus to respond to the temperature predictor, if it is valid. The predictor favored WEE virus and it was practically absent. The predictor did not favor SLE virus and it was active but at a low level and in a limited geographic area. The unusually hot period in all regions of the Central Valley from July to September could have shortened the longevity of *C. tarsalis* and dampened viral activity. However, we have no evidence that this occurred and it is pure conjecture. We know too little about direct relationship of temperature to vector longevity, extrinsic incubation of viruses, and the frequency of vector refeedings. This is a major area of our current research effort.

There was a remote possibility that in the areas of most successful control the vector population was too low to sustain viral activity; and in uncontrolled or less controlled areas, there were such large populations of *C. tarsalis* that most of their feedings were diverted to mammals and this also disrupted transmission. This explanation was most unlikely. We did precipitin tests on several hundred blood-engorged *C. tarsalis* collected from areas where there were high population indices and these mosquitoes had fed predominantly on birds that we must assume were susceptible to infection.

Dr. Lyness will report later in the program on observations he made that a high proportion of female *C. tarsalis* were gravid in collections made from areas where there were large populations. There is a probability that this reflected a high rate of autogeny. There is no question in my mind that if the majority of a *C. tarsalis* population developed its first egg raft without taking a blood meal this would shorten the vector's longevity, reduce the number of successive blood meals and dampen viral transmission. Unfortunately, this possibility also is conjecture and is a subject for further research.

The final variable to consider is that there wasn't an effective available source of virus to allow *C. tarsalis* to initiate viral transmission in the spring and early summer. It is true that in recent years we have had very low levels of viral activity in most of the state and this may have minimized the sources of viruses available in 1969. It is also true that the flooding of extensive areas may have killed many animals or forced them to move and thus reduced potential host populations. However, there were a number of sites under observation where there were ample avian hosts and *C. tarsalis* and where WEE virus had been active every year since 1943. In 1969, viral activity was limited or absent at such localities.

I believe that the only way to summarize the situation is to say that even though we have been studying these infections in California for over 30 years, I do not know why the mosquito-borne viruses did not reach relatively high levels of activity in 1969. If there had been a buildup of virus in rural areas, I believe the control program would have prevented an epidemic of the magnitude of 1952. If I am faced with the same circumstances of extensive flooding in a future winter and spring, I would advise an intensive control program as we can prevent an epidemic and should.

The Future

I would like to turn now to a few additional comments on the future. There is no question that WEE, SLE, California and Turlock viruses remain in this state. There will be a resurgence of their activity and associated diseases when all circumstances favor it. I believe we understand a number of the factors that favor viral resurgence but obviously not all at this time.

There are certain developments in California that we know clearly favor a future increase in viral activity. Water is being moved into many formerly arid areas to develop the areas for recreational, agricultural, and urban usage. This program will provide habitats that favor the development of large populations of *C. tarsalis* and avian hosts for the viruses. Much of the water development program is being carried out with little or no concern for this happening.

Numerous reports on this program deal with the increased resistance of mosquitoes to insecticides and people to the use of pesticides. We possibly are at a time when there are extensive areas where we cannot meet a situation such as faced us this spring and summer. *Culex tarsalis* is increasingly resistant to all licensed insecticides. I have every reason to expect epidemics of mosquito-borne viruses in the future unless new methods and materials are found to suppress the insecticide resistant *C. tarsalis* population.

We continue to have an inability to satisfactorily distribute and manage unusual rainfall, snowpack, and resulting flooding. It is true that a fantastic system of flood control facilities have been developed and they add to our ability to manage water. However, in 1969 we still had extensive farmland put out of production, surplus water was spread on unimproved land, and in many areas the inundation persisted over most of the summer. It taxed our resources seriously and we cannot bear such costs continually.

It has become increasingly clear in recent years that taxation levels will be limited in the future as will be the ability of the landowner to narrow his margin of profits in the interest of mosquito or mosquito-borne disease control.

The preceding is a gloomy and possibly overstated series of problems, but I do not believe so. If we do not have a breakthrough in new and effective means to keep *C. tarsalis* populations at a low level, I can only predict a return to the situation we lived with in the period before 1950. In those early years the number of cases of encephalitis that developed each year depended on the vagaries of the environment and nature with little or no effort to meet them. The difference is that today we know what to expect and what needs to be done to prevent an epidemic. New approaches to control that can be put into effect in the field always seem to have great promise and to be on the horizon. These include:

1. Chemicals and naturally occurring toxins
2. Biologic control
3. Release of genetically incompatible or sterile male mosquitoes
4. The utopia of integrated and economically effective control programs.

I hope these approaches and an increased ability to accomplish source reduction loom large in our future.

It is tempting to consider a new research effort to determine if we can convert our *C. tarsalis* population to one that is genetically incapable of transmitting viruses. We could live with this mosquito if it could not transmit WEE and SLE viruses.

References Cited

Emmons, R.W., and R. Marlor. 1969 Current trends: Encephalitis – California. National Communicable Disease Center Morbidity and Mortality Weekly Report 18, No. 52, p. 451.

Hess, A.D., C.E. Cherubin, and L.C. La Motte. 1963. Relation of temperature to activity of western and St. Louis encephalitis viruses. Am. J. Trop. Med. Hyg. 12:657-667.

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.

1969. Evolving concepts of encephalitis prevention in California. Proc. Calif. Mosq. Control Assoc. 37:3-6.

Sudia, W.D. 1970. Personal communication.

MATERIALS AND TECHNIQUES FOR MOSQUITO CONTROL WITH EMPHASIS ON FIELD EVALUATION[1]

Mir S. Mulla[2], Husam A. Darwazeh[2], Arthur F. Geib[3], Dennis Ramke[4], and Patricia A. Gillies[5]

During the 1969 season, extensive laboratory and field studies were aimed at finding the efficacy of new larvicides, formulations and methods of application against susceptible and resistant populations of mosquitoes.

Laboratory screening studies were conducted on a standard strain of the mosquito *Culex pipiens quinquefasciatus* Say (= *C. p. fatigans* Wiedemann). Field studies were carried out in the Coachella Valley ponds against *Culex tarsalis*

[1]Many persons aided in these studies. The assistance of Harmon Clemens of the Kern Mosquito Abatement District and Manual Nunes of the Tulare Mosquito Abatement is acknowledged.

[2]Department of Entomology, University of California, Riverside.

[3]Kern Mosquito Abatement District, Bakersfield.

[4]Tulare Mosquito Abatement, Tulare.

[5]California State Department of Public Health, Fresno.

Coq., and *Culiseta inornata* (Williston). In the southern San Joaquin Valley (Kern and Tulare counties), most of the work was done on resistant and susceptible populations of the pasture mosquito *Aedes nigromaculis* Ludlow. A highly resistant strain of *C. tarsalis* was also found in Kern County, manifesting a high level of tolerance against ethyl and methyl parathion.

Laboratory Evaluation

In the laboratory, technical materials were dissolved in acetone, yielding 1% W/V solutions. These solutions were serially diluted with acetone. For testing purposes, 100 ml of tap water were placed in 4 oz wax paper cups. Twenty 4th-instar larvae were placed in each cup and the required volumes of the toxicant/acetone solutions were added. Checks were run along with each test. Each treatment was replicated twice and each material was run on 2-3 separate occasions. The mortalities were determined after 24-hr exposure, the values averaged and plotted on probit log paper. The LC_{50} and LC_{90} values were read off these lines and are presented in Table 1.

Several experimental and currently commercialized materials were evaluated for toxicity against 4th-instar larvae of *C. p. quinquefasciatus*. Methyl Dursban® (Dowco® 214) was found to be the most active compound tested. Next in effectiveness was a carbamate insecticide (Chevron RE-11775) which surpassed all others in effectiveness against this species. Several other materials were also quite effective which merit further laboratory and field development.

Slow Release Formulations

Several polyvinyl chloride formulations of Dursban and one formulation of Abate® as plaster of Paris prills were evaluated in 18′ x 18′ x 1′ freshwater ponds in Oasis (Coachella Valley), California. The ponds received water continuously from a pressurized line receiving water from a well. The water level in the ponds was maintained constant by installing toilet tank float valves on the water line in each pond. The water pH in the ponds was 9.0 – 9.5.

Pieces of Dursban plastic formulation were placed in 5 spots in each pond, and the Abate prills (walnut size) were distributed evenly in the ponds. In all cases the formulation sank to the bottom.

Larval counts were taken before and at intervals after treatment, all treated and check ponds were dried up for a period of one week. The ponds were reflooded, with the

Table 1. Laboratory evaluation of new insecticides against 4th instar mosquito larvae of *Culex quinquefasciatus* (1969-70).

Material	Chemical description	LC_{50} ppm	LC_{90} ppm
Dowco 214	*0, 0*-dimethyl *0*(3, 5, 6-trichloro-2-pyridyl) phosphorothioate	0.0010	0.0020
Dursban	*0, 0*-diethyl *0*-(3, 5, 6-trichloro-2-pyridyl) phosphorothioate	0.0010	0.0020
Abate	*0, 0, 0, 0*-tetramethyl *0, 0*'-thiodi-p-phenylene phosphorothioate	0.0010	0.0020
RE-11775	3-(2-butyl) phenyl-N-methyl-N- (phenyl sulfenyl) carbamate	0.0018	0.0026
EPN	*0*-ethyl *0*-p-nitrophenyl benzenethiophosphonate	0.0020	0.0030
Bay 77049	*0, 0*-Diethyl -*0*-(2-chinoxalyl) -phosphorothioate	0.0032	0.0054
Bay 75546	2-(*0, 0*-diethylthionophosphoryl) -3-bromo-5, 7-dimethylpyrazolo-pyrimidine	0.0040	0.0070
TH-346 (Cidial or Phenthoate)	*0, 0*-dimethyldithiophosphoryl-l-phenylacetate	0.0048	0.0069
Bay 85950	Phosphorothioic acid, *0, 0*-dimethyl *0*-[4-cyanoisopropylthio-methylthio-] -phenylester	0.0050	0.0070
Bay 82231	Phosphorothioic acid, *0, 0*-dimethyl *0*-[4-(α-cyanobenzylthio)-phenylester	0.0050	0.0080
Bay 79845	2-(*0, 0*-diethylthionophosphoryl)-3-chloro-5, 7-dimethyl-pyrazolo-pyrimidine	0.0050	0.0080
VCS-506 (Phosvel)	*0*-(2, 5-dichloro-4-bromophenyl) *0*-methylphenylthionophosphorate	0.0050	0.0090
Fenthion	*0, 0*-dimethyl *0*-[4-(methyl=thio)-m-tolyl] phosphorothioate	0.0050	0.0090
Lindane	1, 2, 3, 4, 5, 6-hexachlorocyclo=hexane	0.0060	0.0080
Dowco 217	dimethyl 3, 5, 6-trichloro-2-pyridyl phosphate	0.0060	0.0100
Methoxychlor	1, 1, 1-trichloro-2, 2-bis=(p-methoxyphenyl) ethane	0.0180	0.0300
Bay 99485	Not released	0.0235	0.0350
Bay 88991	α-[(*0, 0*-diethyl-phosphoryl)-oximino] -phenylacetonirile	0.0250	0.0400
Bay 93820	*0*-[*0*-carbisopropoxyphenyl] , *0*-methylphosphoroamidothiomate	0.0300	0.0500
GS-13006	*0, 0*-diethyl-*S*- (2-methoxy-1, 3, 4-thiadiazol-5 (4H)-onyl-(4)-methyl) dithiophosphate	0.0340	0.0600
Bay 92114	Not released	0.0470	0.0750
Bay 91273	*0*-[*0*-carbisopropoxyphenyl] , *0*-ethylphosphoroamidothiomate	0.0800	0.1400
Landrin	3, 4, 5-trimethylphenyl methyl carbamate	0.0880	0.1500
Bay 38799	*0*-cyclopentyl-N-methyl-phenyl carbamate	0.1000	)0.1000
Bay 85194	Not released	0.1000	)0.1000
Bay 85032	1, 1-dimethyl-4-indanyl-N-methyl carbamate	)0.1000	–
Bay 38800	*0*-cyclopentenyl-N-methyl-phenyl carbamate	)0.1000	–

Table 2. Evaluation of slow-release formulations of Dursban in plastic and Abate in Plaster of Paris prills for the control of mosquito larvae in experimental ponds.[1] (1969)

Chemical & formulation (%)	Dosage ppm	Average number of larvae and pupae/five dips sample																	
		Pre-treat			Post-treatment (days)														
					7			21			42[3]			49			56		
		1-2	3-4	P	1-2	3-4	P	1-2	3-4	P	1-2	3-4	P	1-2	3-4	P	1-2	3-4	P
Dursban (23)	0.05	16	4	1	37	6	1	26	4	0									
Dursban (33)	0.05	16	3	0	21	5	0	13	5	0									
Dursban (41)	0.05	48	10	2	36	13	0	16	5	1									
Dursban (50)	0.05	47	11	2	181	30	5	78	20	3									
Abate (3)	0.05	24	4	0	50	9	1	28	8	1									
Check	–	36	8	1	54	14	1	18	7	1									
Dursban (23)	1.00	10	3	0	25	19	2	3	2	0	1	0	0	1	1	0	20	8	0
Dursban (33)	1.00	16	7	0	8	11	1	0	0	0	0	0	0	12	1	0	9	6	0
Dursban (41)	1.00	22	4	1	35	16	4	32	4	2	11	8	3	26	9	0	34	16	0
Dursban (50)	1.00	78	20	3	18	7	1	1	8	1	4	8	1	6	5	0	16	14	0
Abate (3)	1.00	27	9	1	5	1	0	4	1	0	1	0	0	15	0	0	33	14	0
Check	–	22	11	1	15	4	0	2	2	0	0	1	0	10	3	0	23	15	0

[1]All ponds were sampled by taking 5 dips per pond. The five dips then were concentrated into one sample and preserved with alcohol. Samples were taken prior to treatment, and weekly after treatment. All the samples were counted under a dissecting microscope in the laboratory. Chunks of Dursban plastic formulations were placed in 4 corners and the center of the ponds. Each concentration was replicated twice, and two ponds left untreated for check. Abate prills were evenly distributed in the ponds.

[2]After sampling, water from ponds was turned off for drying.

[3]The ponds were dried for 12 days and reflooded 34 days after start of treatment and samples obtained 10 days after reflooding.

formulations (especially the plastic ones) still visible in the ponds. Mosquito breeding ensued and the larval population was assessed for an additional two weeks. The larvae breeding in the ponds were mostly *C. tarsalis*. Some *C. inornata* larvae were also breeding in the ponds.

None of the formulations yielded any marked reduction in the breeding of mosquitoes (Table 2) for any length of time. It appears that the 23% Dursban polyvinyl chloride formulation gave some control of breeding after the second flooding, but this reduction does not look too significant.

The PVC-Dursban and Abate plaster of Paris formulations were also evaluated for release in the laboratory by adding desired amounts of the formulations to water in one-gallon mason jars. The release pattern was studied over a period of a week or so. The magnitude and extent of release were quite low in these studies to achieve mosquito control.

Further detailed studies on these and other slow-release formulations are necessary before any conclusions as to the efficacy of these formulations can be made. Concentration in the formulation, concentration added to the water, surface-release relationships are some of the factors which require critical evaluation.

Resistance to Larvicides

Resistance levels in two species of mosquitoes, namely *A. nigromaculis* and *C. tarsalis* were studied. It was for the first time that populations of *C. tarsalis* could not be controlled with the conventional organophosphate insecticides such as ethyl parathion, methyl parathion and fenthion during the 1969 season.

In the Kern County studies, *C. tarsalis* populations in the James Canal area were found to be resistant to fenthion, Dursban, methyl parathion and ethyl parathion (Table 3). Based on these data, it is expected that these materials can still be employed against this species during the 1970 season. Whether these materials will remain effective for some time to come, has to be seen. The *A. nigromaculis* populations in both the City Sewer Farm area and Smith pastures were still quite susceptible to fenthion, Dursban and methyl parathion. Populations in the Smith pastures were slightly resistant to ethyl parathion and this level has not increased over previous years. Pasture mosquitoes in these pastures are not routinely and intensively subjected to larvicidal treatment pressure.

In the Tulare County, resistant populations from three pastures which were previously confirmed for resistance to some organophosphate materials, were evaluated (Table 4). The three populations showed a high level of resistance to ethyl and methyl parathion. They were also tolerant to Abate. Although some tolerance was manifested against fenthion, Dursban and EPN, it is altogether possible that these materials can still be employed during the 1970 season. Variability in the data is such that a two-fold variation

Table 3. Susceptibility levels of Kern County mosquito larvae to organophosphorus larvicides (September – October 1969).[1]

Chemical	Location	Species	Average 24 hour % mortality at indicated conc. (ppm) 0.001	0.005	0.008	0.01	0.1
Fenthion	James Canal	*Culex tarsalis*	–	–	5	20	100
Dursban	James Canal	*Culex tarsalis*	0	13	–	55	–
Me parathion	James Canal	*Culex tarsalis*	–	10	–	33	100
Ethyl parathion	James Canal	*Culex tarsalis*	–	20	–	30	100
Fenthion	City Sewer Farm	*Aedes nigromaculis*	–	–	–	100	100
Dursban	City Sewer Farm	*Aedes nigromaculis*	–	93	–	100	–
Me parathion	City Sewer Farm	*Aedes nigromaculis*	–	–	–	100	98
Ethyl parathion	City Sewer Farm	*Aedes nigromaculis*	–	–	–	20	53
Fenthion	Smith Pasture	*Aedes nigromaculis*	–	100	–	100	100
Dursban	Smith Pasture	*Aedes nigromaculis*	95	100	–	100	100
Me parathion	Smith Pasture	*Aedes nigromaculis*	–	100	–	100	100
Ethyl parathion	Smith Pasture	*Aedes nigromaculis*	–	85	–	88	95

[1] Third-instar larvae were collected from the breeding sources and transported to the laboratory. They were placed in tap water and then subjected to various concentrations of the larvicides, added as acetone solutions to the cups. Checks were also run with each test, and each treatment replicated twice. Larvae from the same location were assessed for susceptibility 2–3 times during the season.

seems to be normal within the experimental procedure.

Field Evaluation-Irrigated Pastures

Several materials were evaluated against susceptible and resistant pasture mosquitoes in Kern and Tulare counties. The materials were applied by air or by hand. Both aqueous sprays and granular formulations were employed in these studies. Details of method of application and formulations are included in the tables.

(A) Aqueous Sprays. Aqueous sprays were applied by air at the rate of 0.5 gallon for the lower dosage and at 1.0 gallon per acre for the higher dosage. The airplane flew at an altitude of 5-15 feet, and the flight was made under relatively calm weather conditions.

The experiments were run in two pastures in Tulare County where the pasture mosquito *A. nigromaculis* has been known to be resistant to ethyl parathion, methyl parathion and several other organophosphate insecticides (See Table 4). Vegetation in the Torrez pasture was relatively well grazed and short, but the grass in Sanchez pasture was rather rank and lodged during the treatments with some of the materials. All materials evaluated in Torrez pasture were effective in yielding 100% or nearly to 100% control of the larvae at the rate of 0.1 pound of actual material per acre (Table 5). Larvae in the plots treated with Bay 78182 during the post-treatment count were only found under clumps of grass in isolated puddles where penetration by the spray droplets was not possible.

In the Sanchez pasture, Akton® and Supracide® were highly effective at both rates. Fenthion, Dursban and methyl parathion sprays failed to give good control of larvae when these materials were tested at 0.1 lb/acre. It is possible that the nature of the plant cover may have interfered with the effectiveness of fenthion and Dursban. As can be seen from Table 4, the larvae in this pasture are still quite susceptible to fenthion and Dursban. Based on their susceptibility level the fenthion and Dursban treatments at 0.1 pound/acre, should have resulted in good to complete control of the larvae. Lack of penetration due to the heavy plant cover is to be suspected in these situations.

Table 4. Susceptibility levels of three OP resistant populations of *Aedes nigromaculis* in Tulare County to organophosphate larvicides during the 1969 season.[1]

	24–hour lethal concentrations in ppm					
	Pacheco Pasture		Torrez Pasture		Sanchez Pasture	
Material	LC_{50}	LC_{90}	LC_{50}	LC_{90}	LC_{50}	LC_{90}
Ethyl parathion	.19	.42	.38	.93	.26	.79
Methyl parathion	.13	.50	.22	.95	.16	.54
Fenthion	.008	.016	.013	.026	.006	.01
Abate	.024	.036	.024	.05	.024	.038
Dursban	.004	.01	.004	.012	.005	.008
EPN	.007	.016	.008	.031	.01	.016

[1] Larvae were collected in the field, and brought to the laboratory. When they reached early 4th instar, 20–25 larvae were transferred to disposable cups containing 100 ml of water. A range of concentration of each material in acetone solution was studied against the larvae.

Table 5. Field evaluation of new mosquito larvicides as aqueous sprays against OP-resistant populations of the pasture mosquito *Aedes nigromaculis*. (1969)

Material & formulation	Dosage lbs/acre	Avg. no. larvae/dip Pre-treat	Post-treat	% Reduction
	Torrez Pasture – Tulare County			
Bay 78182 EC_2	0.1	8	0.3	96
	0.2	6	0.4	93
Check	0.0	6	8.0	0
Dursban EC_4	0.05	15	1.0	93
	0.10	18	0.0	100
Check	0.0	10	17.0	0

Material & formulation	Dosage lbs/acre	Avg. no. larvae/dip Pre-treat	Post-treat	% Reduction
	Sanchez Pasture – Tulare County			
Fenthion[1] EC_7	0.1	1.8	0.8	56
Dursban[1] EC_4	0.1	2.1	2.3	0
Methyl parathion[1] EC_5	0.1	3.2	2.7	16
Check	0.0	2.5	4.7	0
Bay 77488 EC_4	0.1	5.0	0.0	100
	0.2	7.0	0.0	100
Check	0.0	3.0	4.0	0
Akton EC_2	0.1	5.0	0.0	100
	0.2	7.0	0.0	100
Supracide EC_2	0.1	14.0	0.6	96
	0.2	11.0	0.0	100
Check	0.0	11.0	15.0	0

[1]These experiments were conducted early in the season when the pasture grass was not grazed sufficiently and the plant cover was very rank and lodged. Other tests were conducted later on in the season by which time the grass was well grazed by cattle. The Torrez pasture was also characterized with relatively short forage cover.

(B) Granular Formulations. Various granular formulations of several larvicides were applied by aircraft or manually to irrigated pastures either as a pre-hatch or post-hatch treatment. The tests were conducted in pastures inhabited by OP-resistant or susceptible populations.

Carbofuran applied as granules at the rate of 0.1 and 0.2 pound/acre of actual material both as post-hatch and pre-hatch treatments yielded complete control of OP-resistant as well as susceptible larvae (Table 6). The mosquitoes in Smith pasture are slightly tolerant to ethyl parathion, but not tolerant to methyl parathion or fenthion (See Table 3). On the other hand, *A. nigromaculis* populations in Torrez and Sanchez pastures in Tulare County are resistant to ethyl and methyl parathion. This species in this area also has some tolerance to fenthion, a material currently used for its

Table 6. Field evaluation of mosquito larvicides applied as granular formulations to irrigated pastures for the control of OP-resistant and susceptible *Aedes nigromaculis* populations.

Material and formulation	Treat–time	Dosage lbs/acre	Average number larvae/dip Pre-treat	Post-treat	% Reduction
		Sanchez Pasture – Tulare County OP-Resistant			
Carbofuran 2%G	Post-hatch	0.1[1]	9	0	100
Sand Core		0.2[1]	10	0	100
Check		0.0	3	4	0
Carbofuran 2%G	Post-hatch	0.1	2	0.2	95
Sand Core		0.2	3	0	100
Check		0.0	4	4	0
		Smith Pasture – Kern County OP-Susceptible			
Carbofuran 2%G	Pre-hatch	0.22[2]	–	0	100
Check		0.0	–	75	0
Dursban 1%G	Pre-hatch	0.05	–	0	100
Fertilizer		0.10	–	0	100
Check		0.0	–	45	0
		Torrez Pasture – Tulare County OP-Resistant			
Dursban 1%G	Pre-hatch	0.05	–	6	15
Fertilizer		0.10	–	5	30
Check		0.0	–	7	0

[1]Applied manually. All others applied by air.

[2]Three consecutive biweekly treatments were conducted. Complete absence of breeding in the treated plots each time following treatment. During first flooding after termination of treatment, breeding recurred in the treated plots.

Table 7. Insecticidal drip application for the control of larvae of resistant strains of the pasture mosquito *Aedes nigromaculis*. (Torrez pasture Summer 1969)

Chemical and formulation	ppm	pounds/acre	check number	Average no. of larvae/dip at dist. from water valve (ft) 1000	1500	2000
Methyl parathion EC5[1]	0.25	0.21	1	0.3	0.4	0.2
" "	0.25	0.21	2	0.4	0.3	0.3
" "	0.25	0.21	3	0.2	0.4	0.3
Methyl parathion EC5[2]	0.50	0.33	1	0.8	1.0	5.3
" "	0.50	0.33	2	0.9	2.0	17.0
" "	0.50	0.33	3	1.4	7.2	13.5
Check	–	–	1	1.0	2.0	2.0
Check	–	–	2	2.0	5.0	4.0
Check	–	–	3	2.0	3.0	6.0
Fenthion EC7[3]	0.25	0.24	1	0.0	0.3	0.3
" "	0.25	0.24	2	0.0	1.5	1.6
" "	0.25	0.24	3	0.0	0.0	0.0
Ethyl parathion EC4[4]	0.30	0.26	1	1.7	6.7	16.3
" "	0.30	0.26	2	0.5	2.8	15.9
" "	0.30	0.26	3	2.3	4.5	1.6
Check	–	–	1	10.0	9.7	6.2
Check	–	–	2	6.1	11.2	3.9
Check	–	–	3	5.1	3.5	4.9
Dursban EC4[5]	0.20	0.20	1	0.0	0.0	2.0
" "	0.20	0.20	2	0.0	2.7	2.8
" "	0.20	0.20	3	0.0	0.2	1.5
Dursban EC4[6]	0.38	0.27	1	Dry	Dry	24.0
" "	0.38	0.27	2	Dry	Dry	20.0
" "	0.38	0.27	3	Dry	Dry	8.0
Dursban EC4[7]	0.38	0.27	1	0.0	2.2	9.5
" "	0.38	0.27	2	0.0	25.0	7.0
" "	0.38	0.27	3	0.0	1.2	3.6
Dursban EC4[8]	0.45	0.30	1	0	1	4
" "	0.45	0.30	2	1	2	28
" "	0.45	0.30	3	2	6	6
Check	–	–	1	12	7	3
Check	–	–	2	8	4	7
Check	–	–	3	4	15	6

[1]Me. Parathion: 2500 ml of EC5 containing 3.1 lbs of actual material applied in 15 hours, through 0.16 orifice. Canal pump used for irrigation.

[2]Me. Parathion: One gallon of EC5 dripped in 14 hours, through 0.18 orifice.

[3]Fenthion: 2160 ml of EC7 = (3.5 lbs actual) mixed with 1000 ml of diesel oil and dripped through 0.16 orifice for 14 hours. Well water used for irrigation.

[4]Ethyl parathion: One gallon of EC4 dripped for 14 hours through 0.16 orifice. Well water used for irrigation.

[5]Dursban: 2500 ml of Dursban EC4 (3 lbs of actual material) dripped in for 9 hours through 0.10 orifice. Canal water used for irrigation for 14 hours.

[6]Dursban: One gallon (4 lbs actual) dripped through 0.12 orifice for 14 hours. Canal water used for irrigation.

[7]Dursban: One gallon of Dursban EC4 dripped in for 14 hours, through 0.12 orifice. Canal water used for irrigation.

[8]Dursban: 4500 ml of Dursban EC4 containing 4.5 lbs of actual material dripped in for 16 hours through 0.12 orifice. Well water used for irrigation.

control. It also shows some cross tolerance to Dursban. On account of this low level of cross tolerance, Dursban sprays and granules failed to control these mosquitoes in tall and heavy grass canopy while complete control was achieved in Smith pastures. The failure of granules of Dursban could in part be attributed to its slow release characteristics, not releasing sufficient quantity of the toxicant to overwhelm the slightly tolerant strain of pasture mosquitoes.

Drip Application of Emulsifiable Concentrates

Emulsifiable concentrate formulations of organophosphate larvicides were dripped into irrigation water, spread over the pastures. The tests were conducted in two areas. A number of experiments were conducted in Tulare County where the pasture mosquito *A. nigromaculis* was resistant to most of the organophosphates. The other series of tests were conducted in Kern County in an area where the pasture mosquito is still susceptible to most of the organophosphates.

(A) Drip Application in Resistant Pasture. The John Torrez pasture located on Avenue 184 and Road 80, 5 miles south of Tulare was selected for these tests. The experimental area consisted of three fields, each having three checks (75′ x ½ mile) per field. Irrigation water was either pumped from a well at the rate of 1200 gpm or from an irrigation canal at the rate of 1500 gpm. The duration of irrigation per each field was about 14-16 hours, and each field was irrigated every 10-14 days.

The concentrates were dripped into the water stream from a constant head gravity flow through disc orifices of 0.12-.18 inch depending on the strength of the concentrate and its viscosity. For metering larger volumes, the larger orifices were used and the smaller orifices for delivering smaller volumes per unit time.

Since the mosquitoes in this pasture were resistant to ethyl and methyl parathion (See Table 4), these two materials were dripped at higher rates than normally used in mosquito control. Methyl parathion was applied at 0.25-0.50 ppm in the flowing irrigation water (Table 7). This rate was equivalent to 0.21 and 0.33 lb/acre based on the area treated. Ethyl parathion was used at the rate of 0.30 ppm or 0.26 lb/acre. Neither one of these two materials yielded any marked level of larval control. The notion that drip applications might prove effective against resistant populations was dispelled.

Fenthion at the rate of 0.25 ppm or 0.24 lb/acre, gave good but not complete control of the larvae. The level of control was 100% at the upper end of the field, but it dropped further down the checks from the valves.

Four experiments were conducted with Dursban. The rates of Dursban were: 0.20, 0.38, 0.38 and 0.45 ppm or 0.20, 0.27, 0.27 and 0.30 lb/acre respectively. In none of the tests, control of larvae was complete. Good to complete control of larvae was achieved at the upper end of the field only.

It is interesting to note that continuous dripping of Dursban, even at a rate as high as 0.45 ppm, did not pro-

Table 8. Evaluation of solenoid automatic valves to regulate the flow of emulsifiable concentrate insecticides into irrigation water for the control of pasture mosquitoes. (Smith Pastures 1969)

Material and formulation	Flow rate Timer setting (min.) on	off	Orifice (in.)	Dosage ml/hour	ppm	Average no. of larvae/dip at indicated dist. from valve (ft) 1000	1500	2000
Methyl parathion EC5	1.0	9.0	0.22	160	0.21	0	0	46
Check	–	–	–	–	–	39	70	56
Methyl parathion EC5	2.7	7.3	0.16	180	0.24	0	0	0
Methyl parathion EC5	3.7	6.3	0.14	180	0.24	0	0	0
Check	–	–	–	–	–	79	101	49
Methyl parathion EC5[1]	3.7	6.3	0.14	180	0.24	0	0	3
Methyl parathion EC5[1]	5.0	5.0	0.14	240	0.20	0	0	0
Check	–	–	–	–	–	12	5	6
Methyl parathion EC2[2]	4.0	6.0	0.16	390	0.20	0	0	30
Check	–	–	–	–	–	10	33	12
Methyl parathion EC2	5.0	5.0	0.14	390	0.20	0	0	0
Check	–	–	–	–	–	17	4	63
Dursban EC4	1.0	9.0	0.20	108	0.11	0	0	61
Check	–	–	–	–	–	28	43	88
Dursban EC2[3]	4.0	6.0	0.14	300	0.15	1	1	0
Supracide EC2	4.5	5.5	0.14	402	0.2	0	0	0
Check	–	–	–	–	–	25	24	35

[1](EC5) formulation diluted to (EC3) with espesol solvent.

[2]Long irrigation cycle. 35 checks irrigated in 4 days.

[3](EC4) formulation diluted with Sunland Automotive diesel to (EC2).

duce good control of slightly resistant *A. nigromaculis*. A lower level of concentration (0.15-0.2 ppm) of Dursban dripped in water spread on a susceptible pasture (Smith pastures, Kern County) yielded complete control of the larvae (See Table 8). It thus appears that drip applications of highly water insoluble materials such as Dursban and Fenthion, do not yield good or complete control of somewhat tolerant populations of pasture mosquitoes.

(B) Drip Application in Susceptible Pastures. An automatic solenoid-timer system was evaluated for gravity dripping of concentrates in Smith pastures in Kern County. *A. nigromaculis* in these pastures are still susceptible to methyl parathion, and other organophosphates (See Table 3). The timer was set for various fractions of a 10 minute cycle to turn on and off the system automatically. As the timer came on, it triggered an electric solenoid valve to permit dripping of the concentrates into the flowing head of water pumped from a well at the rate of 2000 gpm. During the "off" cycle the concentrate stopped dripping into the water.

Dursban EC_4 dripped in this manner yielded good control of larvae up to the 1500 ft distance from the valve, when the timer was on for 1 minute and off for 9 minutes (Table 8). Increasing the "on" cycle to 4 minutes, using Dursban at 0.15 ppm, this material yielded almost 100% control at all distances from the valve.

Since methyl parathion is still effective against this population (See Table 3) 7 drip experiments were conducted to find the optimum "on" and "off" cycle of the system. In most cases the "on" and "off" cycle of 4:6 or 5:5 yielded the best results. A cycle of 1:9 was not satisfactory.

An experimental organophosphate insecticide Supracide (GS-13005) dripped at 0.2 ppm produced excellent control of the larvae when this material was metered at an "on" and "off" cycle of 4.5:5.5. The rate of application of this material was the same or less than that of methyl parathion. Several other tests (not reported here) with this material also produced excellent results. It will be desirable to evaluate this material further in areas where the mosquitoes are highly resistant to organophosphates. Since this material has a higher solubility in water than either fenthion or Dursban, it is expected that this material should be carried down with the water more readily toward the lower end of the field irrigated.

MOSQUITO CONTROL INVESTIGATIONS – DEVELOPMENT OF SOME SHORT AND LONG TERM TECHNIQUES

Mir S. Mulla, Toshiaki Ikeshoji, and Husam A. Darwazeh
Department of Entomology, University of California, Riverside

Studies on the development of mosquito control technology at the University of California, Riverside, California, emphasized work on both short-term and long-term solutions to the mosquito problem. As part of the long-term study, chemical factors influencing selection of oviposition sites by female mosquitoes were investigated. For the first time it was discovered that there are naturally occurring chemical factors which are involved in the oviposition behavior of our most problem species of mosquitoes such as *Aedes nigromaculis* Ludlow (pasture mosquito), *Culex tarsalis* Coq. (encephalitis mosquito) and *Aedes taeniorhynchus* (Wiedemann), a salt marsh mosquito along the coast.

Another important development was the discovery of naturally occurring chemical factors which are elaborated when mosquito larvae are highly overcrowded in their breeding containers. These chemical factors are highly active against young larvae, at the undetermined, but small doses tested. They decimate the young larvae either by killing them or slow down their growth to such an extent that they remain babies for many days or weeks.

As part of a study finding short-term solutions to the mosquito problems in California, several new organophosphate and organocarbamate mosquito larvicides were evaluated against resistant and susceptible species. A number of materials were found to yield good to excellent control of resistant pasture mosquitoes.

Application techniques were also studied and developed. It was found that continuous dripping of emulsifiable concentrates into irrigation water yields good control of susceptible pasture *Aedes*. This method of application, however, did not produce good control of these mosquitoes. Rankness of vegetation influenced efficacy of aerial sprays. High and lodged vegetation decreased efficacy.

These and various other studies accomplished during the 1969 season are described below.

Overcrowding Factors

Field observations have been repeatedly made on the absence of mosquito breeding in certain breeding sources and also on the sudden decline of mosquito larval and pupal populations following heavy breeding for a period of time in certain types of breeding sources. Larvae of a dead, predacious mosquito *Culex (Lutzia) fuscanus*, have also been observed in a habitat where heavy larval population of the prey mosquito *Culex pipiens quinquefasciatus* Say (= *C. p. fatigans* Wiedemann) prevailed in the field. Sudden declines of larval populations have also been observed in laboratory colonies. Such sudden crashes in population density occur at certain frequency and at times are not due to presence of predators or pathogens or shortage of food supply.

Overcrowding of larvae in laboratory rearing units has resulted in die off of larvae, retardation of growth and emergence of deranged adults with low level of fecundity. These effects have been observed for the contemporary generation.

We hypothesized that larvae cultured under overcrowded conditions produce factors which are toxic to the succeeding generation(s). In order to prove this hypothesis, mosquito larvae were cultured under various conditions in the laboratory. The results of these studies are as follows:

Third-instar larvae of the mosquito *C. p. quinquefasciatus*, raised under overcrowded conditions (5-7 larvae/ml.) produced chemical factors which were highly toxic to the 1st-instar larvae of this species. In addition to being highly toxic to the younger larvae, the overcrowding factors slowed down the growth and development of younger larvae and produced morphological aberrations in the larvae exposed to the suspension of extracts of these factors.

Overcrowded cultures of larvae maintained under septic and aseptic conditions, showed approximately similar activity when their supernates were evaluated against younger larvae. Infusions of larval food (without any larvae), under septic and aseptic conditions also produced some toxic factors, but the nature and quantity of these factors produced were different from those elaborated in overcrowded larval cultures. Tap water control and less crowded larval cultures were devoid of these factors.

The toxic overcrowding factors were ether-extractable, but some factors also were extracted in the aqueous layer as determined by bioassay techniques. Ether extract of larval homogenates was free of the toxic overcrowding factors.

The overcrowding factors isolated from cultures of *C. p. quinquefasciatus* and streaked on thin layer chromatograms showed 2 zones where biological activity was most obvious. Ether eluate from one of these two zones was further streaked on a thin layer chromatogram using a second solvent system. The most active materials were located at the solvent front. Materials from this zone as well as two other zones showed quick killing action and residual activity against 1st-instar larvae. In some tests, the overcrowding factors manifested biological activity for as long as 22 days.

Overcrowding factors of *C. p. quinquefasciatus* showed considerable activity against 1st-instar larvae of *C. tarsalis*, *Aedes aegypti* (L.) and *Anopheles albimanus* Wiedemann. In one experiment overcrowding factors from a larval culture of *A. aegypti* were extracted with ether. This material showed high activity against larvae of *C. p. quinquefasciatus*. Ethanol elution of concentrated ether extract showed considerably higher biological activity than the water suspensions of the same materials. It is postulated that ethanol either synergizes the factors or makes them more available to the larvae.

The overcrowding factors produced naturally by mosquitoes themselves are highly self limiting. Once these compounds are chemically known and are synthesized, they will provide control of mosquitoes in nature. One thing in favor of these substances is that they are already present in nature, and further application by man would cause little or no environmental pollution problem.

Oviposition Attractants

It is a well known fact that mosquitoes lay their eggs in certain bodies of water and not others. A number of complex factors prevailing in the breeding sources of mosquitoes influence selection of oviposition sites by mosquitoes and the deposition of eggs in these sources. Among these factors, volatile chemicals have been found to attract mosquito adults to certain sites for oviposition.

Earlier studies on oviposition attractants for *C. p. quinquefasciatus* provided a new stimulus to embark upon a study of oviposition attractants of other mosquitoes. Occurrence and biological characterization of these attractants were investigated for four representative species of mosquitoes breeding in different habitats in California. These mosquitoes were *C. p. quinquefasciatus*, *C. tarsalis*, *A. nigromaculis*, and *A. taeniorhynchus*.

Water samples were collected from four different sites in which mosquito larvae were either breeding or expected to breed; an artificial polluted pond for *C. p. quinquefasciatus*, an artificial unpolluted pond for *C. tarsalis*, an irrigated pasture for *A. nigromaculis*, and a salt-marsh for *A. taeniorhynchus*.

One hundred or 120 litres of the field water from each breeding site were distilled to get the initial one tenth aliquot of distillate, which was redistilled to 1/5 volume. The final distillate was extracted with ethyl ether. The ether was removed under a vacuum evaporator and 2 ml of the attractant concentrate was obtained.

The concentrate was bioassayed in the following manner: For the *Culex* species, a 50 ml-beaker trap, containing 10 ml tap water, was provided with a filter paper strip treated with either 5 microlitre or 50 microlitre of the concentrated attractant. The beaker was covered with a wire net cone and set in a mosquito cage. Egg-rafts laid in the traps were counted the next morning. For *Aedes* species, the walls of a small paper portion cup were treated with the material. The cup was then filled with moistened cotton pad. The number of eggs laid on the cotton pad of the treated cup was compared with that laid on the untreated cup the next morning. Ratio of the number of egg-rafts or eggs laid on the treated unit against that on the untreated unit was worked out.

The following experimental results were obtained. (1) Oviposition attractants of *C. tarsalis*, *A. nigromaculis* and *A. taeniorhynchus* were found for the first time to exist in their natural breeding waters and these attractants provided stimuli to attract the particular species. *C. tarsalis* attractant was 5.1 and 7.1 times as attractive as distilled water to this species at 5 to 50 microlitres of the concentrate respectively. *A. nigromaculis* attractant was 4.3 and 7.3 times as attractive as distilled water at 5 and 50 microlitres respectively. *A. taeniorynchus* attractant drew 100% oviposition in distilled water. The attractant of *C. p. quinquefasciatus* yielded a ratio of 4.7 and 2.8 at 5 and 50 microlitres respectively, versus distilled water. (2) Oviposition attractants of *C. tarsalis*, *A. nigromaculis* and *A. taeniorhynchus*, however, were not attractive to other species of mosquitoes and showed repellency in some cases. There was one exception to this as the *A. nigromaculis* attractants were attractive to *C. tarsalis* at the dose of 5 microlitres. *C. p. quinquefasciatus* was attracted to the attractants of all species and not specific in its response.

The availability of synthetic oviposition attractants similar to those produced in nature by bacteria and other microorganisms will provide a novel method for the control of pest and vector mosquitoes. By utilizing these attractants, mosquito oviposition may be intensified in a small portion or portions of the breeding sources where the eggs or larvae can be eliminated by other procedures.

Evaluation of Larvicides and Application Techniques

A number of newer mosquito larvicides were evaluated against susceptible and resistant mosquitoes in Kern and Tulare counties. Bay 77488 and 78182 yielded complete control of resistant pasture *Aedes* at the rate of 0.1 lb/acre. Similarly Akton®, Supracida® (GS-13005) and carbofuran at the rate of 0.1 lb/acre produced complete control of the resistant pasture mosquitoes. Dursban® granules (1%) on the other hand yielded poor control of OP-resistant *Aedes* at 0.1 lb/acre, but produced 100% control of OP-susceptible *Aedes* at the rate of 0.05 lb/acre. It is probable that fenthion and Dursban could control OP-resistant mosquitoes during the coming season.

Several materials were evaluated against OP-resistant pasture *Aedes* by the continuous drip application method. Methyl parathion, ethyl parathion at rates as high as 0.33 and 0.26 lb/acre respectively, yielded poor control of mosquito larvae. At a distance of 1500-2000 feet from the valve there was little or no control of the OP-resistant mosquitoes. Fenthion at 0.25 lb/acre applied by the drip method yielded good but not complete control of these resistant *Aedes*. The level of control was about 75% at the lower end of the field. It was discouraging to find Dursban, a recently registered product for mosquito control, when applied at rates as high as 0.3 lb/acre, produced poor control of these OP-resistant mosquitoes. There was no control of larvae at the lower end of the field. Dursban has not been used for mosquito control in California, and it appears that parathion resistant mosquitoes have a cross tolerance to Dursban. It is also possible that absorption and filtration of Dursban on the organic material of these pastures is too high. Water quality might also play a role.

Aerial application of aqueous sprays of fenthion, methyl parathion and Dursban, each material applied at 0.1 lb/acre, yielded little or no control of mosquitoes in a pasture with high and lodged vegetation. Dursban at 0.05 lb/acre, applied as aqueous spray to an adjacent pasture having low, well grazed vegetation, yielded complete control of the larvae. The *Aedes* mosquitoes in both pastures were parathion (ethyl and methyl) resistant.

Continuous drip application of concentrates is not feasible under most operational conditions. This is due to the small volume of the concentrate needed to be metered through a small orifice. It was suggested that intermittent or discontinuous delivery of concentrates might overcome some of the difficulties involved in continuous drip application. It therefore became necessary to investigate the ratio of "on" and "off" periods for metering of the concentrates.

Solenoid-timer systems were fixed to reservoirs of insecticidal concentrates on several wells in Smith pasture in NW Kern County. The *Aedes* mosquitoes here are susceptible to methyl parathion and Dursban but slightly tolerant to ethyl parathion. Using methyl parathion concentrate (EC 5), metered at an average rate of 0.20 to 0.24 ppm in the irrigation water, good to complete control was obtained when the timer was set for 3 to 5 minutes on and 7 to 5 minutes off. Level of control was poor when the metering device was on for 1 minute and off for 9 minutes. It looks like a 50/50 (off for five minutes and on for 5 minutes) cycle will yield good results. Dursban concentrate (EC 2) was applied at the rate of 0.11 to 0.2 ppm. Control was not complete at .11 ppm, with the metering device on for 1 minute and off for 9 minutes. Complete control was obtained when the rate was increased to 0.15 ppm and the on-off times were 4 and 6 minutes respectively.

Mosquito Control in Sewage Lagoons

Emulsifiable concentrates of several materials were poured into the incoming sewage stream which was distributed over 6 ponds with three in a row connected in series. Abate at 0.3 – 0.4 lb/acre yielded complete control initially. In winter months the duration of control was far longer than 4 weeks, while in the spring the level of control was complete for 5 weeks in 5 ponds, but only two weeks in one pond. This pond probably was shut off before sufficient quantity of insecticide flowed in.

Supracide (GS-13005) or EC 2, at the rate of 0.4 lb/acre did not yield complete control of mosquitoes in the sewage lagoons, although level of control was quite high initially. Fenthion EC 4, at 0.4 lb/acre, yielded good control but this lasted only for two weeks or so. Ciba C-9491 (EC 3) at the rate of 0.3 lb/acre gave good control initially but the population came up rapidly within 2 to 3 weeks. Akton (EC 2), at the rate of 0.3 – 0.4 lb/acre, yielded good to complete control but the population buildup was apparent within 3 weeks after treatment.

Three tests were run with Dursban (EC 4) in these sewage lagoons. In two tests, made at the rate of 0.3 and 0.4 lb/acre, complete control of mosquitoes was achieved for more than 77 days after treatment. In another test (0.3 lb/acre), mosquito breeding resumed within 56 days after treatment.

From these studies it was concluded that Dursban is by far the most active and residual material under these testing conditions. It was also shown that the pour-in method provides an easy and effective method for controlling mosquitoes in terminated sewage systems.

Slow Release Formulations

Dursban was solubilized in polyvinyl chloride plastic. The concentrations of Dursban were: 23%, 33%, 41% and 50%. Five to six chunks of each formulation were placed in a breeding pond 20′ x 20′ to yield a concentration of 1 ppm of Dursban in the water. Abate was formulated in plaster of Paris balls. The balls were 0.5 – 1.0 cm in diameter. The concentration of Abate in the plaster was 3% and the balls were thrown in the ponds to yield a concentration of 1 ppm of Abate in the pond.

After application of the slow-release formulation the ponds were kept flooded and sampled for mosquito larvae for 3 weeks, after which they were dried and reflooded 10 days later and then sampled for larval populations.

Neither Dursban nor Abate yielded complete control of larvae in the treated ponds. There was a mediocre level of control in the ponds treated with the 23 and 33% formulations of Dursban and the plaster of Paris formulation of Abate. The other two formulations of Dursban were ineffective. There was no mosquito control after the second

Table 1. Effectiveness of (IMC-10001) pathogen against larvae of *Culex pipiens quinquefasciatus* in pans containing 25 larvae in 2000 ml of water.[1]

	Cumulative percent mortality after treatment (days)														
Conc.	2			3			4			6			7		
ppm	L	P	A	L	P	A	L	P	A	L	P	A	L	P	A
2nd Instar															
1	10	0	0	26	0	0	44	0	0	84	0	0	90	0	0
10	40	0	0	68	0	0	76	0	0	94	0	0	98	0	0
20	72	0	0	78	0	0	82	0	0	98	0	0	100	0	0
Check	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4th Instar															
1	4	2	14	6	2	20	6	2	22	6	4	26	(64%) emerged		
10	0	32	20	0	36	22	0	38	26	0	42	30	(28%) emerged		
20	4	32	18	4	34	28	8	36	32	4	36	36	(24%) emerged		
Check	0	0	0	0	0	0	0	0	0	0	0	0	(100%) emerged		

[1]Twenty-five larvae were placed in white enamel pans, containing 2000 ml of tap water. The material was suspended in water, and the required amount was added with 1 ml pipet to the water surface. Larvae were fed approximately (5 mg) every 48 hours, and dead larvae, pupae and adults were recorded and removed from the pan every 24 hours. Two replicates per concentration and two checks were run concurrently.

flooding.

Slow release formulations offer some good possibilities for mosquito control. These formulations have to be further studied. The efficacy of these formulations is not sufficient at this time and only the surface has been scratched as far as this technology is concerned.

Microbial Toxins

A microbial toxin preparation known as IMC–10001 (International Minerals and Chemicals Corp.) was evaluated against two species of mosquitoes. The mosquito species studied were: *Culex p. quinquefasciatus* and *A. albimanus.* Second and 4th-instar larvae of each species were employed.

The powder preparation was tested at 1, 10 and 20 ppm. Larval mortality as well as adult emergence was observed over a period of 7 and 10 days for the two species.

IMC–10001 was more toxic to the 2nd-instar larvae of *C. p. quinquefasciatus* than to the 4th-instar larvae of this species. Noticeable mortality occurred after 48 hours of exposure of 2nd-instar larvae at all concentrations, reaching maximum level after 7 days, at which time 9, 98 and 100% of the larvae were dead at 1, 10 and 20 ppm respectively (Table 1). Mortality of 4th-instar larvae, however, was very low at all concentrations, amounting to only 4% at the 20 ppm concentration, 6 days after treatment. Mortality in the pupal stage, however, was moderate. At the end of 7 days of exposure the adult yield for the 1, 10, and 20 ppm concentrations was 64%, 28% and 24% respectively. Emergency of adults was almost 100% in the checks.

The first-instar larvae of *A. albimanus* were also more susceptible to IMC–10001 than the 4th-instar larvae. Eight days after treatment 24 and 80% of the larvae had died at 1 and 10 ppm concentrations (Table 2). Adult emergence and pupal mortality were not assessed in this case and it is very likely that considerable mortality occurred in these stages.

Mortality in the 4th-instar larvae of *A. albimanus* was quite low. It did not go above 10% at the 20 ppm concentration, 8 days after treatment. Mortality in the pupal and adult stage, however, was quite high. The final yield of adults was 26%, 8% and 0% at 1, 10 and 20 ppm concentrations. The yield of adults in the check treatment was 92%.

Bacterial preparations offer some good possibilities for mosquito control. Their initial effectiveness, long-term effectiveness, specificity and formulations, however, have to be studied further.

Petroleum Oils

Petroleum oils were some of the first control agents used for mosquito control in the larval stages. For example, Kerosene oil was used prior to the turn of the century for mosquito control in the United States. As far as known the use of petroleum oils for mosquito control or other arthro-

Table 2. Effectiveness of (IMC-10001) pathogen against larvae of *Anopheles albimanus* in pans containing 25 larvae in 2000 ml of water.[1]

	Cumulative percent mortality after treatment (days)											
Conc.	4			6			8			10		
ppm	L	P	A	L	P	A	L	P	A	L	P	A
2nd Instar												
1	0	0	0	4	0	0	24	0	0			
10	6	0	0	16	0	0	80	2	4			
Check	0	0	0	0	0	0	4	0	0			
4th Instar												
1	0	22	8	2	24	20	2	34	38	(26%) emerged		
10	6	18	16	6	20	18	8	48	36	(8%) emerged		
20	4	10	8	12	20	18	10	70	20	(0%) emerged		
Check	0	0	0	0	0	0	0	0	8	(92%) emerged		

[1]For methods and procedure see footnote in Table 1.

pods has caused no resistance in any of the insects controlled.

Due to the continuous and progressive development of resistance in *A. nigromaculis* (the pasture mosquito) and *C. tarsalis* to organophosphate larvicides, studies on the efficacy of petroleum oils and their formulations for mosquito control were initiated. It is a well known fact that petroleum oils will kill eggs, larvae and pupae of mosquitoes. In this regard, they are more effective than the organophosphorus and organocarbamate materials which kill only mosquito larvae, but not the other immature stages which are present along with larvae at the same time.

In order to study and improve the efficacy of petroleum oils, several commonly available fractions were selected for study. These fractions were: Toxisol FLC, Toxisol 142, and FLIT MLO. The mode of action and formulation efficacy of these oils against mosquito larvae and pupae were studied.

The question as to how oils kill mosquito larvae and pupae has baffled researchers for many years. This question was answered by planning and expediting many experiments to measure the cuticular and aerial respiration of mosquito larvae and pupae. It was found that the mode of action of oils is a complex one. The old theory of "suffocation" was found to be the mean reason for kill, but suffocation is enhanced by certain components of oils which excite larvae and pupae so they can come in contact and pick up sufficient quantities of oil in their respiratory channels and on their cuticle. The aromatic content of an oil is generally responsible for irritation and excitation of the larvae.

The old concept that a uniform oil film is required for effectiveness was disproven. It was found that oils which formed uniform films for 5-7 days were much less effective than oils forming discontinuous films. Thickness of the film and presence of lenses in discontinuous films are important for increased activity of oil films.

The addition of biodegradable surface active agents increased the activity of oils against mosquitoes. With some surfactants there was synergistic action, where the action of petroleum oils was enhanced materially. By using a proper surfactant, it would be possible to lower the rates of petroleum oils used for mosquito control.

PATHOGENS OF MOSQUITOES[1]

Eldon L. Reeves
Division of Biological Control, University of California
Riverside

1969 was an exciting and fruitful year in the Mosquito Pathology Laboratory at U.C. Riverside. We have researched several potentially effective pathogens and other alternative biological methods of mosquito control, some of which will be discussed here.

For the past four years we have been surveying selected mosquito breeding sites in southern California in search of diseased mosquito populations. In 1967, while making our first surveys in the Santa Ana Mountains in Orange County, we checked Ladd Creek and Silverado Creek, into which Ladd Creek empties. The potholes along the sides of each of these streams, for all practical purposes, appeared to be acceptable breeding sites for mosquitoes, but no larvae could be detected. The local residents indicated that mosquitoes were no problem in their area and they were not aware of any insecticidal treatments in their canyon for several years. Subsequent consultation with the Orange County Mosquito Abatement District personnel confirmed the natural low level of mosquitoes in these two canyons. The presence of a green filamentous alga was obvious and no other factor was readily detectable that could have suppressed mosquitoes so thoroughly over the several miles of streambed during June and July. Therefore, samples of this alga and some of the stream water were transported to our laboratory and bioassayed against mosquito larvae. Larvae that were placed in the stream water failed to develop and when the alga was cultured in tap water for a few days this water became toxic to test larvae. Based on these initial observations, a Ph.D. dissertation problem was outlined and assigned to Shankar Amonkar. Dr. Amonkar completed his dissertation in December, 1969 on the toxic metabolites produced by five species of algae isolated from mosquito breeding habitats, in Orange and Riverside counties (Amonkar 1969).

Ladd and Silverado creeks are flowing streams each spring and part of the summer. Depending upon the amount of rainfall in the area they dry up as the season progresses. Winter rains revive these streams and an overwintering inoculum of this alga initiates new growth each spring, as early as March or April. This particular macrofilamentous green alga, known as culture no. AL-001, was studied in our laboratory, pure cultured and identified as *Cladophora glomerata* (Table 1).

Based on the encouraging preliminary results obtained with AL-001, other algal isolates from potential mosquito breeding habitats were screened and a total of five species of mosquito active algae were isolated. These active isolates fall into a variety of taxonomic groups, including one green, macro-filamentous, AL-001, *C. glomerata;* one blue-green micro-filamentous, AL-003, *Schizothrix friessii;* one green unicellular, AL-005, *Chlorella ellipsoidea;* and two species of a higher, plant-like form of green alga that bears male and female bodies, AL-004, *Chara fragilis* and AL-010, AL-011 and AL-012, *Chara elegans.* Two isolates of a nontoxic alga, AL-014 and AL-015, *Spirogyra* sp. were carried as control for this work.

Each isolate was pure cultured and the culture water bio-

[1]This work was supported in part by U.S. Department of Agriculture Research and Service Contract No. 12-14-100-8164(33), Agricultural Research Service, Washington, D.C.

Table 1. Algal isolates from Orange and Riverside counties that were determined to be active against immature stages of mosquitoes (Amonkar, 1969).

Sample Number	Division	Species Identity	Gross Characteristics
AL-001	Chlorophyta	*Cladophora glomerata* (L.) Kuetzing	Macro, green, filamentous
AL-003	Cyanophyta	*Schizothrix friesii* (Ag.) Gom. (=*Os. pseudogeminata* var. *unigranulata* Biswas)	Micro, blue-green, filamentous
AL-004	Charophyta	*Chara fragilis* Desvaux	Macro, green, plant-like with ♂ and ♀ fruiting bodies
AL-005	Chlorophyta	*Chlorella ellipsoidea* Gerneck	Micro, green, unicellular
AL-010 AL-011 AL-012	Charophyta	*Chara elegans* (A. Braun) Robinson	Macro, green, plant-like with ♂ and ♀ fruiting bodies

assayed for activity. Then dehydrated algal material from each was extracted with hot methanol and this crude extract purified using column chromatography. Each of the active algae yielded a chromatographically pure compound that was toxic for immature mosquitoes and the two inactive algae that were extracted in the same manner did not yield toxic fractions. The active fraction from each of these seven isoates and the corresponding fraction from AL-014 and 015 were bioassayed against 4 species of laboratory reared *Culex* and *Aedes* as well as field collected insecticide resistant strains of the pasture mosquito, *Aedes nigromaculis*.

The differences in the bioassay results between the treatments and controls were very highly significant at the 0.1% level. Histopathological studies on *Aedes triseriatus* larvae treated with material from AL-001 showed at least one mode of action and the target tissues. The epithelial lining of the gut-wall had been disrupted and the gut contents had stopped moving and had become compacted. In contrast, the normal untreated larvae had their epithelial lining intact and the digestive tract contents were moving through in a normal rhythmic fashion.

These findings have a two-fold value in practical application. The toxic strains of algae could be propagated in rice fields, ponds, and streams to suppress the larval populations of mosquitoes. Secondly, the active compounds could be chemically characterized and commercially synthesized along with their analogues, and dispersed at the mosquito breeding sites like other chemical insecticides.

Being botanical larvicides, there is probably less risk of larvae developing resistance to these compounds than to the usual chemical insecticides. Furthermore, these compounds are normally released by these algae into the aquatic environment, thus bringing about a natural population control of the mosquitoes. No adverse effects to fish or aquatic insect predators have been observed. The normal cohabitants of mosquito habitats have been observed to be very healthy in the presence of these active compounds, at levels that suppress mosquito development. This would indicate that these compounds are rather specific natural larvicidal agents.

These findings have significance on a worldwide basis, as well as statewide. The fact that certain algae can be useful in the control of *A. aegypti*, which is a worldwide disease vector, as well as *A. nigromaculis*, which prevails in irrigated pastures of California, makes this research relevant.

Now, here is an additional bit of research that shows how one research problem can lead to the next. Because of the strong correlation between the odor released by crushed fresh *Chara* and the odor released by crushed garlic, a garlic oil fraction was isolated and tested and found to be highly larvicidal against five species of third instar *Culex* and *Aedes* larvae, including the pasture mosquito, *A. nigromaculis* (Amonkar and Reeves in press). LC_{50}'s for the five species were in the range of 2 to 6 ppm of this crude fraction of garlic oil.

Further efforts are being directed towards purification of the active principle and study of its pathological effects on mosquito larvae. The chemical characterization and the commercial synthesis of the active principle of garlic would permit the utilization of this botanical insecticide in much the same manner as other pesticides. This could be an interesting approach to mosquito control.

A major accomplishment in the "detection and evaluation of mosquito pathogens" has been the isolation of a bacterial pathogen from moribund *Culex tarsalis* larvae that is effective against mosquito larvae of the genus *Aedes*, including *A. aegypti*, *A. nigromaculis*, *A. sierrensis*, and *A. triseriatus*. This isolate, designated BA-068, is a crystalliferous Bacillus and tentatively considered to be a new species. This bacterium consistently produces two parasporal bodies per cell when cultured on artificial medium, as well as when it occurs in a host insect. This characteristic appears to be a stable genetic marker, which morphologically makes a very effective label.

We isolated this bacterium from diseased *C. tarsalis* larvae but it is rather ineffective as a pathogen against *Culex* larvae, however, it is a very effective pathogen against *Aedes* larvae. This may indicate that it has evolved in association with the *Culex* genus, and as many parasites have done, developed a workable relationship that in most instances is less than fatal to its host. In contrast, when associated with *Aedes* larvae the same bacterium is the etiological agent of a fatal infection.

BA-068 is readily cultured in the laboratory and its taxonomic position is being determined. Results of laboratory bioassays against first instar *Aedes* larvae show 97-98% mortality with 0.9 x 10^6 spores/ml in the 4 species tested, with very low mortality in the controls. Comparable mortality readings were obtained with third instar *Aedes* larvae with 4.5 x 10^6 spores/ml and 4% mortality in the controls.

Preliminary field tests against highly insecticide resistant strains of *Aedes nigromaculis* larvae have been conducted in irrigated pastures in Tulare and Kern counties and look good.

At the time of these tests we had only a limited amount of material and the volume of water in the test areas was actually greater than we had hoped for. Therefore, the rate of application was consistently lower than ideal. In general, we were very pleased with the results. Theoretically, when the diseased larvae died they deposited some bacterial spores on the muddy surface of the soil which can act as an inoculum against the next generation of mosquito larvae which will occur following the next irrigation. If so, this would be at least a partially self-perpetuating system.

Another alternative in insecticides that may find some application in certain integrated control programs is the use of certain types of Cruciferae seeds which are capable of producing a mucilaginous halo around each seed when placed in water (Reeves and Garcia 1969).

When the seeds of *Descurainia sophia*, *D. pinnata* or *Lapidium flavum* are placed in water the dehydrated mucilage contained in their seed coats pops out in less than a minute. When larvae come in contact with this mucilaginous layer they become irreversibly attached.

Two other local Cruciferae weeds that are effective larvae traps are the shepherd's-purse, *Capsella bursa-pastoris* and the short podded mustard, *Brassica geniculata*. There are approximately 5 million seeds of the shepherd's-purse per pound, each seed being only 1 mm in length. The maximum number of larvae observed attached to one seed has been 27. The larvae become attached by their oral brushes and struggle and die. The seeds can be heat treated to destroy the viability and prevent germination, thus eliminating the problems associated with dispersing live weed seeds. Application of these seeds could be made using hand applicators, power blowers, or by airplane.

In summary, there are a variety of potentially useful organisms that could contribute to the biological control of mosquitoes if we were to research them and adapt them to our needs.

Acknowledgments

The author wishes to express his gratitude to S.V. Amonkar and C. Garcia, Jr. for their technical assistance in the field and laboratory; to A.F. Geib, Kern MAD, D. Ramke, Tulare MAD, and J.H. Kimball, Orange County MAD and other personnel in each of these mosquito abatement districts for their assistance.

References Cited

Amonkar, S.V. 1969. Fresh water algae and their metabolites as a means of biological control of mosquitoes. Ph.D. Dissertation, University of California, Riverside.

Amonkar, S.V. and E.L. Reeves. 1970. Mosquito control with active principle of garlic, *Allium sativium*. (In press).

Reeves, E.L. and C. Garcia. 1969. Mucilaginous seeds of the Cruciferae family as potential biological control agents for mosquito larvae. Mosq. News 29:601-607.

MOSQUITO TOXICANTS – A LOOK AHEAD

Wm. M. Rogoff
Entomology Research Division, USDA Fresno[1]

Mosquito control is a complex operation that involves the cooperative efforts of people having widely differing reasons for participating in this activity. I would like to share with you my interpretations of some of the reasons for decision making in mosquito control and my projection of things to come. To be more specific, the primary interest of the mosquito abatement district manager is the achievement of fewer mosquitoes in his district without side effects and costs that may outweigh benefits. The primary interest of the businessman who markets equipment or chemicals is to provide a product needed by the public that will bring about financial improvement of his company. If these were the only interests involved, it would then be easy to conclude that commercial interests may have an undue influence on the choice of mosquito control methods. Also in such a situation a particularly heavy burden would be placed on the abatement district manager to keep the claims made for various products in their proper perspective.

Fortunately for the manager, many other parties are concerned with his decision making process. Government and university scientists have a multitude of interests in mosquito control that are, in varying degrees, independent of practical applications on the one hand and of commercial interests on the other. The manager therefore has at his disposal an array of recommendations from Federal and State (including educational institutions) sources in addition to the direct information he gets through his own reading, consultation, and experience. However, there is no doubt in my mind that the strongest influence affecting the choice of procedures for mosquito control is the personal experience of the people that are directly responsible. Thus it is the apparent efficacy of a procedure, conditional on its cost, that serves as the primary basis for deciding on its use.

When I first came in contact with mosquito control activities in the early 40's as a Navy entomologist, I found great emphasis on long-term (source) reduction. Thus, draining, impoundments, clearing margins, straightening and shaping ditches, and installation of concrete lined channels were highly regarded. The use of parasites and predators was considered an unattainable ideal, except per-

[1] 5544 Air Terminal Drive, Fresno, California 93727.

haps for *Gambusia.* Short term alleviation of mosquito problems depended on a few materials such as larvicidal oils or Paris green, or pyrethrum as a localized adulticide.

The proliferation of insecticides that followed the development of DDT provided tools capable of achieving results that were previously beyond reach. Indeed, these tools were so effective that by the late 40's almost total dependence was being placed on them. The commercial value of the materials in use justified large expenditures to find more such insecticides. Expenditures increased not only in entomology, but also in chemistry, toxicology, physiology, and many other interrelated disciplines. Problems of insecticide resistance were (and are) exasperating, but during the 50's and early 60's they served as added stimuli for further research and for the development of even greater numbers of insecticides.

The rate of development of new materials has now been drastically reduced. The cost of development is vastly greater than it was 20 years ago, and the amount of data required to establish efficacy, safe residue tolerance, characterization of breakdown products, and safety to man, domestic animals, and wildlife is so great that a decision by industry to develop a product must be carefully weighed. However, until recently, the potential for profitable return on investment was primarily a matter of the normal risks of competition. That is, given the anticipated cost of development, the question was whether the expected market would be pre-empted by a superior or cheaper competitive product. Naturally, as registration requirements have become more stringent, additional risks have been introduced. Moreover, questions of possible long range, low level toxicity are particularly vexing because they can often only be answered, if at all, late in the course of development of a product. Indeed, a material may seem to be well within safety tolerances and hence go beyond label approval to plant construction and marketing, before a critical hazard is identified and confirmed.

The potential hazards associated with the use of chemical insecticides have always been recognized, but in my opinion, some individuals have either exaggerated or minimized their importance. However, the current interest in reduction of all environmental pollution has produced some public opposition to almost any application of insecticides. This anti-insecticide attitude adds one more problem for the developer of new materials. Today, in addition to the magnitude of his dollar investment, problems of registration, the activities of competing firms, and the size of the potential market, he must also consider the possibility of public condemnation and attendant legal restrictions.

What then, is the outlook? First, I expect to see further legal restrictions as well as social and economic pressure against the development and use of insecticides. From an operational point of view, control will be more difficult, because, at least initially, we can expect increased costs and even reduced effectiveness. This could result in a general shake-out of marginal materials and the departure of many manufacturers and formulators who are unwilling to assume the increased commercial risks. However, those that remain will probably benefit from increased prices and reduced competition.

Second, the increased operating costs and reduced effectiveness caused by the reduced latitude in the choice of materials will probably result in the development of alternate procedures, chemical as well as non-chemical. However, environmental upsets can be expected from any major disturbing factor, whether it be chemical, cultural, or biological. Therefore, the proper integration of available techniques will require the attention of many persons with diverse training and interests. I believe that responsibility for developing the new procedures will be less that of industry than of publicly supported research. Although I anticipate that non-chemical procedures will be heavily emphasized (compared with the past few decades), good sense will dictate that improved chemical procedures should not be overlooked.

During the next decade, therefore, I expect to see a major research input by ecologists and geneticists in addition to that of chemists, entomologists, and operational personnel. I also expect a considerable degree of frustration. The next level of sophistication will not be easily reached, and I will not be surprised to see some relaxation of restrictions to satisfy the demands for effective control. However, if this relaxation of restrictions occurs, I foresee no return to the situation in which the choice of procedure is left to the judgment of those whose primary objective is insect control. The judgment will be shared broadly, as will the responsibility. I do not mean that decisions will rest with private parties guided only by their own interests or prejudices because that would be bedlam. I do mean that authority must and will be vested in officials representing ecological interests as well as public health, commercial, and operational interests. Therefore, responsibility for success or failure in holding down costs or achieving effective control will also be broadly distributed. In the long run such a development will be healthy and the public will be better served as a result.

1969 RESULTS ON MOSQUITO CONTROL RESEARCH

Charles H. Schaefer
Mosquito Control Research Laboratory
University of California, Fresno

The year 1969 proved to be a challenging but progressive year for the Fresno Laboratory. I will discuss our research results under several categories:

A. – Control of Pasture Mosquitoes

After several years of work on this problem three things have become apparent: (1) There is no easy solution to this problem. While many man years have been invested in an attempt to find improved methods for controlling pasture mosquitoes, no dramatic break-throughs were made and none are apparent at present (2) the biological control approach offers no significant, practical solutions at the present time. The rapidly changing conditions associated with irrigated pastures, coupled with the exceedingly fast development time of pasture mosquitoes, does not provide favorable circumstances for the establishment and maintenance of effective predator populations (3) the combination of chemical control, improved water and land management and the possible use of soil ammendments appears to be the most realistic course for the next few years. It is also possible that this approach will not be adequate, under some circumstances, and that only a political solution will remain.

(a) Chemical Control – While insecticide-resistance continues to be of major significance with respect to controlling *Aedes nigromaculis* (Ludlow), the situation is not altogether hopeless. Insecticide tests of susceptible and organophosphorus-resistant strains of *A. nigromaculis* at Fresno have shown that the resistant strains have a high degree of cross-resistance to most new organophosphorus compounds, but show low tolerance to carbamates. Two new carbamates, which have remarkable toxicity against larvae and adults of both susceptible and organophosphorus resistant strains, were discovered in our testing program. Due to this finding, extensive laboratory and field evaluations were carried out during 1969. Many of California's mosquito abatement districts participated in the field evaluations of Chevron's RE11775 and RE11776; while these tests were expensive to conduct, due to the actual costs and time involved as well as some disruption of operational programs, the results were very significant. RE11776 has been dropped from further testing but the commercial development of RE11775 for the chemical control of mosquitoes is now a likely possibility.

Our tests showed that 0.1 lb per acre of RE11775 will provide larval control of organophosphorus-resistant strains of *A. nigromaculis* and that 0.05 lb per acre is adequate against susceptible populations; RE11775 also gave excellent control of adults at the same rates, and laboratory tests show that it is equal to, or slightly better than, Baygon®. Our studies on RE11775 will continue during 1970 and, assuming that no unforeseen problems develop, we hope to obtain the necessary data to allow the use of this new material in 1971. In summary, RE11775 has proven to be effective against the most resistant strains of *A. nigromaculis* in both the Sacramento and San Joaquin Valleys, it appears to be relatively safe and preliminary cost evaluations are favorable.

One major obstacle which we will encounter with any new chemical from now on is the anti-pesticide movement. The "emotional trauma" that has now swept through the populace is bound to cause regulatory agencies to become more and more reluctant to make approvals. This now necessitates that all of us who realize the importance of chemical insecticides be prepared to take a firm stand with regard to their importance in mosquito control.

(b) Water and Land Management and Possible Use of Soil Ammendments – An ideal way to eliminate the breeding of pasture mosquitoes would be to use irrigation techniques which would not allow water to stand along enough for the completion of larval development. At first this approach sounds simple, but numerous obstacles readily become apparent. Pastures are frequently located on soils which have poor water penetration characteristics. Farmers attempt to improve penetration by allowing water to stand over these lands for many days; I have observed fields where the vegetation turned brown unless this practice was used. Thus, the problem is not due to a simple case of over irrigation. All fields are heterogenous due to inexact leveling, numerous small depressions, e.g., hoof prints, and the frequent presence of low areas caused by border construction. Some of these can be largely reduced by using good techniques of land preparation and management, e.g., using proper border construction and not allowing cattle on wet fields. However, one will never be able to obtain perfect conditions and slow water penetration in depressions will still allow significant mosquito breeding. Even a drainage return system, which can greatly reduce the length of time which water stands on the low end of a field, is not adequate to solve the mosquito breeding problem on many fields. If one could increase water penetration, while also utilizing good methods of water and land management, the entire situation could be greatly improved; this would allow improvement of land productivity while also reducing mosquito breeding. But the obvious question remains, is it economic? The monetary return from pastures located on poor soils is low, but the cost of mosquito control in some areas is approaching, if not already exceeding, the farmers net return!

After consultation with soil experts, the use of gypsum appeared to be the best technique presently available to improve water penetration on the alkaline pastures of the San Joaquin Valley. Presently gypsum costs about $5 per ton (applied) and five or more tons per acre are usually necessary. However, these costs could be reduced substantially by working through a land reclamation program. The basic question then becomes, if the required amount of gypsum, as determined by soil analysis, is applied to "problem pastures", will the effect be sufficient to substantially reduce or eliminate the development of pasture mosquitoes? In order to evaluate the efficacy of using gypsum for this purpose, a major study was initiated during 1969. In cooperation with the Tulare Mosquito Abatement District, Valley Nitrogen Producers, Inc., Fry Aviation Industries, and two farmers, we are studying this problem on two pastures; these fields are located on poor, alkaline soil types in western Tulare County and are representative of the most difficult mosquito control problems. The amount of gypsum required on each check of these fields was determined by chemical analyses. Gypsum was applied at rates equal to the total, one-half or one-third of the required amount as indicated by chemical analyses; some checks were not treated. The fields were then ripped to a depth of 12-14 inches, disked and were seeded with coastal bermuda. A total of 260 tons of gypsum was applied to these plots which included 28 checks having a combined area of 40 acres. Soil samples were taken from three locations on each check after the gypsum applications and at the end of the 1969 growing season. These checks will be resampled at the beginning and end of the 1970 and 1971 seasons as well. All of the soil samples are being quantitatively analyzed for Ca^{++}, Na^{+}, Mg^{++}, Cl^{-}; pH and conductivity measurements are also being made. These data, in addition to observations on the lengths of time of standing water and mosquito production, will hopefully provide some answers to the questions discussed above. It will take a minimum of several years to obtain the necessary information, due to the slow rate with which gypsum is expected to move downward in such soils.

B. – Biology of Pasture Mosquitoes

Further studies on the biology of *Aedes melanimon* Dyar which help to explain the fall dispersal of this species have been conducted by Dr. Miura. In the fall, the extent of nocturnal flight increases greatly and the bimodal peaks of flight activity (at twilight periods), which are characteristic in the spring and summer, are reduced. In the fall, a much greater number of adults can be collected with unlighted, unbaited traps, which indicates a non-specific flight behavior. Winds of 5 mph or more seem to inhibit flight.

Dr. Miura has also completed an evaluation of mass rearing *A. nigromaculis* by induced mating methods. With experience, an average person is able to inseminate 15-20 females per hour; the average egg production was 46 eggs per female (range 15-89) and 60% of the total eggs obtained were viable.

C. – Research on *Culex* Species

During the fall of 1969, significant insecticide resistance was encountered with numerous populations of *Culex tarsalis* Coq. in the lower San Joaquin Valley. Laboratory colonies of five resistant populations were established at Fresno and the levels of resistance, in comparison to a susceptible strain, were determined for Dursban, fenthion and RE11775 (Table 1); it is apparent that RE11775 offers real promise against the organophosphorus-resistant strains.

RE11775 has also shown to be very effective against field populations of fenthion-resistant *Culex pipiens quinquefasciatus* Say larvae at doses as low as 0.025 lb/acre, applied by jeeps. Thus, this new carbamate offers real promise against organophosphorus-resistant strains of *Culex* species as well as for *A. nigromaculis.*

Table 1. Resistance-ratio of resistant strains of *Culex tarsalis* larvae. (LC_{50} R-strain/LC_{50} S-strain)

Strain and Location	RE11775	Dursban	fenthion
Jessup – Kern County	1.7	36	13
James – Kern County	1.5	22	8
Pintail – Kern County	1.3	44	12
Caruthers – Fresno County	1.5	14	7
Melga – Kings County	1.5	9	5

(a) Stability of Dursban in Polluted Water – Since the use of Dursban for controlling mosquitoes in polluted water sources has become common in California, a study was made to determine factors affecting its stability in these habitats. When Dursban is applied to the inlet of a polluted water body, it rapidly becomes widely distributed. Within a few days most of the insecticide deposits on organic solids but agitation causes some redistribution back into the water phase. In the absence of organic matter, Dursban has limited hydrolytic stability which is temperature dependent. These qualities allow for the use of this insecticide in polluted waters for effective and rather long-term control of mosquito larvae. Also, the high organic content of polluted water beds acts as a filter to remove the insecticide from the water; this, coupled with the limited hydrolytic stability of the compound, gives strong indications that insecticide pollution of sub-surface waters will not result, particularly in view of the low doses that are initially applied. While such treatments with Dursban provide many weeks of residual control of *Culex* larvae, we have found low densities of organophosphorus-resistant *C. tarsalis* larvae and pupae developing in two Dursban-treated ponds; bioassay of water organic matter samples from these sources with susceptible *Culex* larvae indicated that the treatments should still have been effective. The total numbers of organophosphorus-resistant *C. tarsalis* breeding in these sources were not large enough to be a control problem, but they provide "seed" which will allow the subsequent spread of the resistant strain. It appears that it would be wise to eliminate such organophosphorus-resistant populations, whenever they are found, with a different type of control agent, e.g., oil. Thus, insecticide-resistance appears to be the main problem which will limit the prolonged use of Dursban for mosquito control in polluted water sources of the San Joaquin Valley.

(b) Overwintering Biology of *C. tarsalis* – Studies on the overwintering biology of *C. tarsalis* adults are continuing. Thus far, we have determined the quantity and identity of lipid components which adults synthesize and then utilize during the overwintering period. Our present investigations deal with identification of the precursors which adults use for the synthesis of these lipids. Details of this study will be presented at the CMCA Entomology Seminar in April 1970.

HOST PREFERENCES OF MOSQUITOES[1]

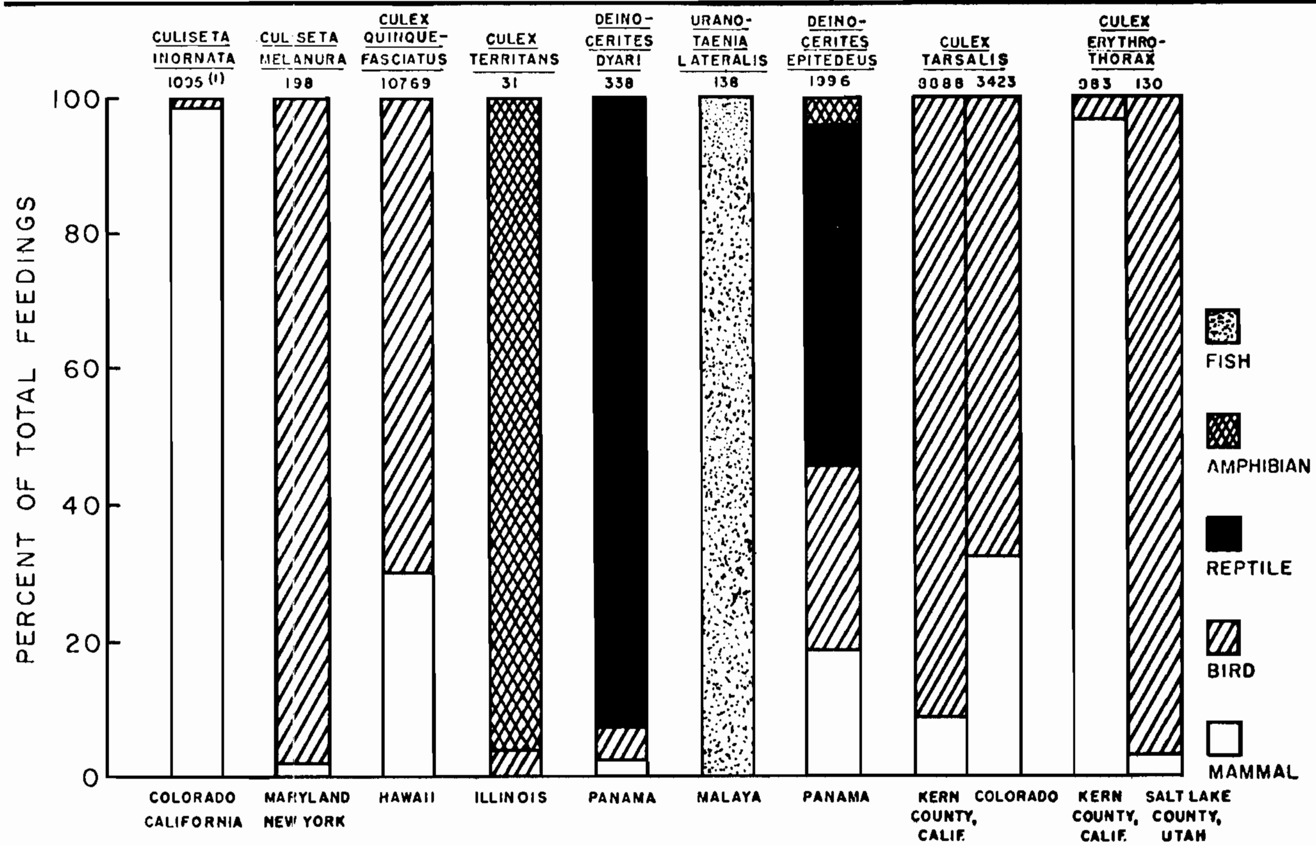
C. H. Tempelis[2]
University of California, School of Public Health
Berkeley

Modifications in the basic precipitin techniques used in the identification of mosquito blood meals and the production of antisera in chickens have enabled us to broaden the testing range for blood-meal identification. To date we have tested over 60,000 mosquitoes representing over 40 species. These mosquitoes have been collected in North America, Hawaii and Panama, and one species *(Uranotaenia lateralis* Ludlow*)* in Malaya.

[1]This research was supported in part by Research Grant AI-03028 from the National Institute of Allergy and Infectious Diseases; and by General Research Support Grant I-SO1-FR05441 from the National Institutes of Health, U.S. Department of Health, Education and Welfare.

[2]Supported by United States Public Health Research Career Development Award 1-K3-AJ-25, 427.

Table 1. Examples of nine basic mosquito host preferences.



Nine basic feeding patterns of possible epidemiologic significance have been observed in our studies. These basic patterns (Figure 1) represent (a) mosquitoes that fed almost exculsively on mammals, e.g., *Culiseta inornata* (Williston), *Aedes vexans* (Meigen), and *Anopheles freeborni* Aitken (Tempelis et al., 1967; Washino and Tempelis, 1967); (b) mosquitoes that fed almost exclusively on birds, e.g., *Culiseta melanura* Coq., *Culex peus* Speiser, and *Culex thriambus* Dyar (Joseph and Bickley, 1969; Tempelis and Washino, 1967; Tempelis and Reeves, 1964); (c) mosquitoes that fed readily on both birds and mammals, e.g., *Culex pipiens quinquefasciatus* Say (Tempelis et al., 1970); (d) mosquitoes that fed almost exclusively on reptiles, e.g., *Deinocerites dyari* Belkin and Hogue (Tempelis and Galindo, 1970); (e) mosquitoes that fed almost exclusively on amphibians, e.g., *Culex territans* Walker (Crans, 1965, unpublished results); (f) mosquitoes that fed exclusively on fish, e.g., *U. lateralis* (unpublished results); (g) mosquitoes that fed on both warm- and cold-blooded animals, e.g., *Deinocerites epitedeus* (Knab) (Tempelis and Galindo, 1970); (h) mosquitoes that demonstrated a seasonal shift in feeding pattern from predominance of feeding on birds in the spring and early summer to feeding on significant numbers of mammals in the mid- and late summer, e.g., *Culex tarsalis* Coq. and *Culex nigripalpus* Theobald (Tempelis et al., 1965; Edman and Taylor, 1968); (i) and mosquitoes that fed in one geographic area almost exclusively on mammals in another area on birds, e.g., *Culex erythrothorax* Dyar (unpublished results).

Mosquitoes that feed almost exclusively on birds could be the primary enzootic vectors of arboviruses for which birds serve as the primary host, e.g., St. Louis encephalitis (SLE), eastern equine encephalitis (EEE), and western equine encephalitis (WEE). *C. melanura* is the primary vector of WEE and EEE in the eastern United States (Hayes et al., 1961; Hayes et al., 1962). This mosquito's almost exclusive preference for birds serves well for the maintenance of EEE and WEE in these hosts, but transmission of virus to man and horse would require a second vector species.

Mosquitoes that feed almost exclusively on mammals could be the primary enzootic and epidemic vectors of arboviruses for which mammals serve as the primary host, e.g., Powassan and California viruses. Attempts have been made to associate *C. inornata* with the transmission of WEE. Although isolations of WEE virus have been made from this mosquito, there is little possibility that this mosquito is involved in the basic transmission cycle of WEE virus because of its almost exclusive preference for mammals.

Host preference patterns of *C. quinquefasciatus* collected in Hawaii and Florida could lead to the interchange of viral agents from birds to mammals because of the ability of this vector to feed readily on both of these groups of animals (Tempelis et al., 1970, unpublished results).

There has been considerable interest in the possible role of cold-blooded animals as reservoirs for arboviruses (Gebhardt et al., 1964; Thomas et al., 1958). For a mosquito to be a primary vector of a virus from a cold-blooded animal, it must feed readily on both cold- and warm-blooded animals. No North American mosquitoes have been found with this type of feeding pattern. *C. territans* has been shown to feed readily on amphibians, but this feeding pattern would not lend itself to transmission of a virus from cold- to warm-blooded animals. An ideal feeding pattern for this type of transmission was exhibited by *Deinocerites epitedeus* mosquitoes collected in Panama. This mosquito fed readily on several different animal subgroups within each vertebrate class (Tempelis and Galindo, 1970). On the basis of its feeding pattern, *D. epitedeus* could serve as an efficient vector for a wide range of viruses from basic cycles to aberrant hosts.

An example of possible geographic factors influencing feeding preferences is the data we have for *C. erythrothorax*. In Kern County, California, this mosquito fed almost exclusively on mammals, while in the Great Salt Lake area of Utah this mosquito fed on birds (unpublished results). Mammals and birds were readily available in both areas, so host availability probably was not a factor. Our data for all other mosquito species that we tested indicated that if there was an almost exclusive preference for either birds or mammals, this was a basic characteristic regardless of area tested. It is possible that these different feeding patterns observed for *C. erythrothorax* indicates the possible presence of two distinct subspecies or species of mosquito.

Seasonal Changes in Feeding Patterns

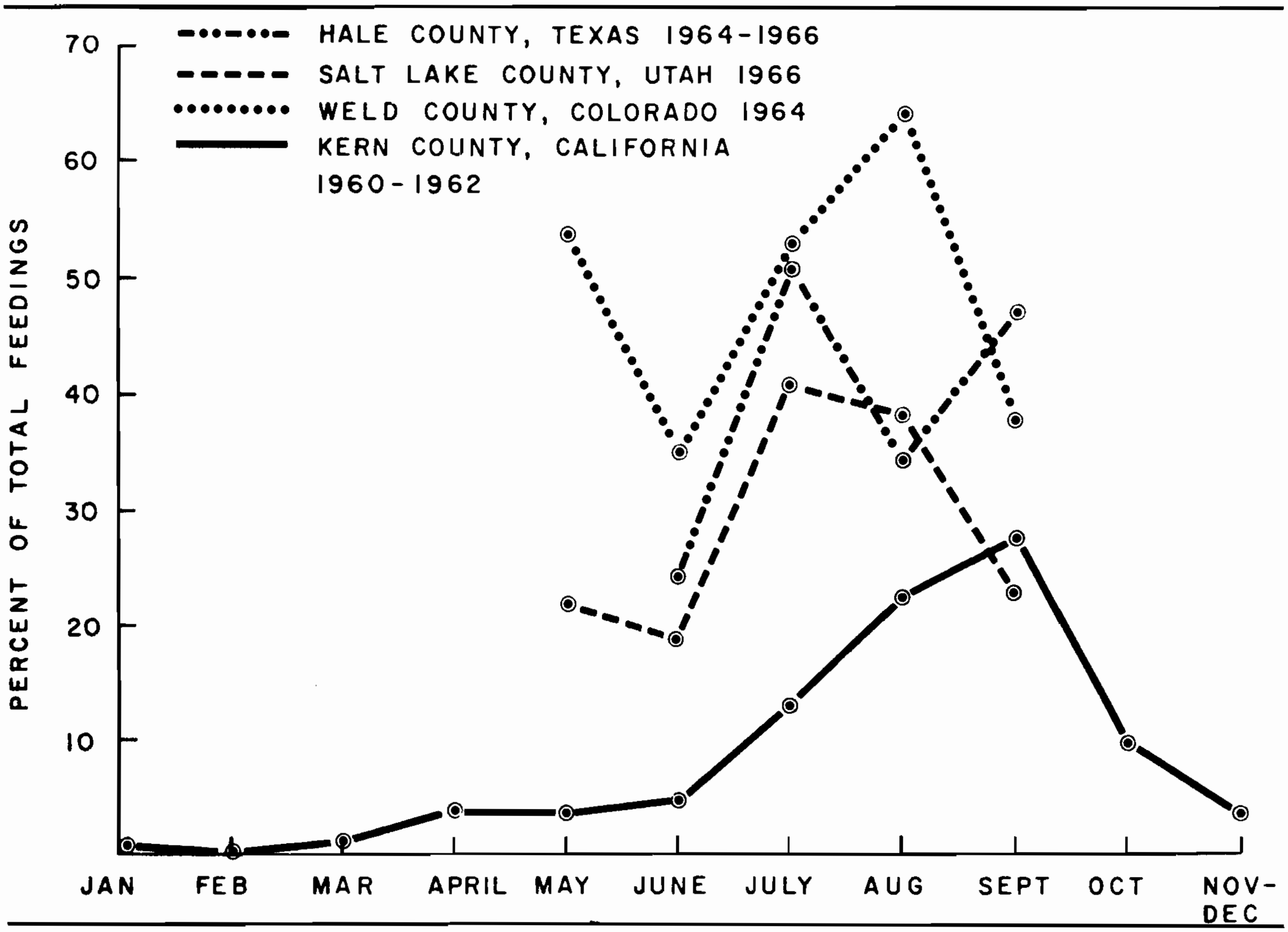
The feeding pattern demonstrated by *C. tarsalis* was the most interesting of all. This mosquito not only demonstrated a versatility in feeding range, but also a change in its feeding preference from birds in the spring and early summer to a significant feeding rate on mammals in the mid- and late summer (Figure 2). Studies of this species in widely separated geographic areas demonstrated that the same basic pattern existed in all of the areas studied. Similar data have been reported by Edman and Taylor (1968) on *C. nigripalpus*, which was thought to be the primary vector of SLE in Florida during the early years of the last decade.

The only association that can be correlated with this shift in feeding preferences was the coincidental increase in *C. tarsalis* populations. The increased numbers of mosquitoes may result in a divergence of *C. tarsalis* from this preferred avian host to secondary mammalian hosts.

Multiple Feedings

In all areas where we have studied the feeding preferences of mosquitoes, there have been only two exceptions to the

Table 2. The monthly percentage of *Culex tarsalis* that fed on mammals in Kern County, California, Weld County, Colorado, Salt Lake County, Utah and Hale County, Texas.



low frequency (less than 0.1%) of multiple host source in a single blood meal. In Hawaii about 1.0% of *C. quinquefasciatus* (Tempelis et al., 1970) and in Texas about 1.0% of *C. tarsalis* had taken multiple feedings (unpublished results). These percentages represent the minimum number of multiple feedings, as two or more feedings taken from the same or closely related species would not be detectable by our precipitin method.

Conclusion

I believe that the capillary precipitin technique using antisera principally produced in chickens, has provided valuable information regarding the feeding preferences of mosquitoes. We have established that there are nine basic feeding patterns and that within most basic feeding patterns there is some variability because of host availability and geographic location. Seasonal changes in feeding patterns have been observed in *C. tarsalis* and *C. nigripalpus.* Both of these mosquitoes are important in the transmission of arboviruses that have their basic cycle in birds and an aberrant cycle in man and domestic mammals. Further studies may indicate that similar feeding patterns may be found in other mosquitoes with similar vector potential.

Multiple feedings do not appear to be a common phenomenon among mosquitoes.

Acknowledgments

These studies would not have been possible without the cooperation of several research units and mosquito abatement districts. I would like to thank them all. My special appreciation to Dr. William C. Reeves for his encouragement and active participation in many of these studies. I am indebted to Mrs. Mary Lofy Rodrick for her capable technical assistance throughout all of these studies.

References Cited

Crans, W.J. 1965. Host preference studies with New Jersey mosquitoes. The Serological Museum, Bull. No. 33, p. 1-4.

Edman, J.D., and D.J. Taylor. 1968. *Culex nigripalpus:* Seasonal shift in the bird-mammal feeding ratio in a mosquito vector of human encephalitis. Science 161:67-68.

Gebhardt, L.P., G.J. Stanton, D.W. Hill, and G.C. Collett. 1964. Natural overwintering hosts of the virus of western equine encephalitis. New Eng. J. Med. 271:172-177.

Hayes, R.O., L.D. Beadle, A.D. Hess, O. Susman, and M.J. Bonese. 1962. Entomological aspects of the 1959 outbreak of eastern encephalitis in New Jersey. Am. J. Trop. Med. Hyg. 11:115-121.

Hayes, R.O., J.B. Daniels, and R.A. MacReady. 1961. Western encephalitis virus in Massachusetts. Proc. Soc. Exp. Biol. Med. 108:805-808.

Joseph, S.R., and W.E. Bickley. 1969. *Culiseta melanura* (Coquillett) on the eastern shore of Maryland (Diptera: Culicidae). Bull. A-161. University of Maryland, Agricultural Experiment Station, College Park, Maryland.

Tempelis, C.H., D.B. Francy, R.O. Hayes, and M.F. Lofy. 1967. Variations in feeding patterns of seven culicine mosquitoes on vertebrate hosts in Weld and Lariner Counties, Colorado. Am. J. Trop. Med. Hyg. 16:111-119.

Tempelis, C.H., and P. Galindo. 1970. Feeding habits of five species of *Deinocerites* mosquitoes collected in Panama. J. Med. Entomol. In Press.

Tempelis, C.H., R.O. Hayes, A.D. Hess, and W.C. Reeves. 1970. The blood feeding patterns of four species of mosquitoes found in Hawaii. Am. J. Trop. Med. Hyg. In Press.

Tempelis, C.H., and W.C. Reeves. 1964. Feeding habits of one anopheline and three culicine mosquitoes by the precipitin test. J. Med. Entomol. 1:148-151.

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

Tempelis, C.H., and R.K. Washino. 1967. Host-feeding patterns of *Culex tarsalis* in the Sacramento Valley, California, with notes on other species. J. Med. Entomol. 3:315-318.

Thomas, L.A., C.M. Eklund, and W.A. Rush. 1958. Susceptibility of garter snakes (*Thamnophis* spp.) to western equine encephalomyelitis virus. Proc. Soc. Exp. Biol. Med. 99:698-700.

Washino, R.K., and C.H. Tempelis. 1967. Host-feeding patterns of *Anophelis freeborni* in the Sacramento Valley, California. J. Med. Entomol. 3:311-314.

THE APPLICATION OF INTEGRATED CONTROL PRINCIPLES TO MOSQUITO CONTROL PROBLEMS

Ray F. Smith
University of California, Berkeley

The question that I would like to put before you this morning is this: "Are we ready to go to integrated control?" I think the answer is a simple "no" and the reasons for this are several. First, I don't think we are desperate enough, as yet, to go to something as difficult and intellectually challenging as integrated control. Frequently I hear statements that "the present chemicals can last a couple of years more and the chemical industry is in the process of developing whole new families of pesticides that will save us." Such statements may or may not be true (personally I doubt that they are); but in addition we are not ready for integrated control for other important reasons (for other pertinent discussion on pesticides see papers by W. M. Rogoff and C. H. Schaefer in this symposium). Integrated control is based on the manipulation of pest populations taking full advantage of natural occurring mortality. However, at present time, we do not know what a mosquito population is – that is, we cannot define and measure mosquito populations from the standpoint of their population dynamics. Furthermore, we know almost nothing about naturally occurring mortality in mosquito populations. Let me elaborate.

The first session of the Food and Agriculture Organization of the United Nations (FAO) Panel of Experts on Integrated Pest Control in 1967 (FAO 1968) defined integrated control as "a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economic injury . . . It is not simply the juxtaposition or superimposition of two control techniques (such as chemical and biological controls) but the integration of all suitable management techniques with the natural regulating and limiting elements of the environment." This is a very wordy statement but it was carefully prepared and it incorporates the basic principles of integrated control. If this statement is not clear, let me use ecological terms and translate this long involved statement by the following. Integrated control is the application of the principles of population ecology toward the goals of pest population management.

This same first session of the FAO panel of experts also said "integrated control derives its uniqueness of approach from its emphasis on the fullest practical utilization of the existing mortality and suppressive factors in the agro-ecosystem." Now let us examine this subject in more detail. Do we know what a mosquito population is? I maintain that we do not. Furthermore, until we do know, we cannot intelligently discuss, analyze, and plan for the management of mosquito populations. We do not know the real population parameters for any stage of any mosquito. Counts made from light trap collections, at resting stations, with dippers, etc., do not define the real population (Southwood 1966). At best they may be fairly good indices of the population numbers. But they do not tell us the real or absolute size of the population. Furthermore, most often they tell us little, if anything, about the activity of the population or future changes in the population.

In a few places, some determined efforts have been made to determine absolute mosquito population levels of both larvae and adults – particularly through mark-and-recapture techniques. The results have not been too successful. The task is not easy. The uneven dispersion of adults and larvae in the environment, the unusual movements hither and yon of both within their habitats, the uneven increments to the populations, and other strange habits of mosquitoes make the determination of population size very difficult. Nevertheless, solid information on this point is needed if we are to understand mosquitoes and move toward integrated control.

One of the reasons we must understand mosquito populations better is to establish economic levels. Agricultural entomologists use the term economic level; but, perhaps for pest mosquitoes it would be best to say tolerance level. We must have some reasonable level of tolerance for mosquito populations. If we say the level is zero, then to get satisfactory control we must always seek complete elimination or eradication of the mosquitoes. From the viewpoint of most ecologists this is usually an impossible goal and the practitioner of mosquito control is finding this out too. But some mosquito control specialists say you cannot have tolerance levels for mosquitoes which are vectors of human disease pathogens. I question very seriously if this is correct. In some situations when populations of mosquitoes drop to low levels, the pathogen ceases to move from host to host and may even die out in the reservoir host. In other words, a threshold level of the population is passed and the transmission cycle is not maintained. Reeves has presented evidence that a threshold level of *Culex tarsalis* is necessary to maintain transmission cycles of western equine encephalitis and St. Louis encephalitis and also that clinical cases in man and horses virtually disappeared when light trap catches dropped to 10 *Culex* females or less per night (Reeves 1968, 1969).

Pest mosquitoes in urban areas are a different matter. But even for pest mosquitoes there are certainly some tolerable levels especially if one considers the economics of the situation. I am sure that you will agree that one mosquito biting a charming but influential suburban housewife can create an intolerable situation in a mosquito abatement district office. However, this is not cause to fog an entire city with a pesticide. Also, we must remember in evaluating the tolerable level of a mosquito population not all individuals in the population are involved in biting suburban housewives or in vectoring disease pathogens.

How can we utilize natural mortality in mosquito control? First, we must know something of what natural mortality is. Many long lists have been published of the natural enemies of mosquitoes and other arthropods of medical importance. These lists are but a first step in the evaluation of mortality. Unfortunately, they are of little use to us in evaluating the precise nature and value of natural mortality. Most of the parasites, predators, and pathogens given in these lists contribute little of significance to the total mortality. In most cases we do not know any of the details of their impact. We have only the fact of an association but need information not only that a particular parasite kills mosquito larvae, but also such information as what numbers it can kill in different habitats and with variable densities of mosquito larvae. This kind of information is hard to develop, but it must be acquired if we are to understand and utilize natural enemies effectively.

In recent years there have been some very interesting studies of adult mosquito populations. These have involved mark-and-recapture techniques and age-composition evaluations. They show considerable promise but the results are uneven and variable. This approach has provided rough estimates of "losses" from the various categories in the population. However, these "losses" are not necessarily mortality as emigration may also be involved. What is needed is refinement of these studies to reveal the causes of the losses. There are suggestions that much of the premature mortality of both larvae and adults results from physical changes in the habitat, e.g., desiccation. In any case, there are often many good mosquito situations (i.e., apparently ideal for mosquito production) that do not produce adult mosquitoes. We need to know why.

It would be very useful to know what was the ultimate fate of each individual in a population of say 10,000 mosquito eggs. As of now we do not have the procedures to do this, but the suggestions are coming from life table studies of insects of importance to forestry and agriculture. I am not suggesting that mosquito abatement districts make such life table studies as part of their operation and planning for mosquito control. Rather, this is a difficult and sophisticated research area that could produce information to be used in more efficient mosquito control of the future.

Integration of Biological and Chemical Control – Much of the discussion about integrated control today revolves around the integration of chemical and biological control. This is because these two techniques are our most effective tools in the fight against insect pests. However, this discussion usually involves agricultural situations where the significance of introduced biological control or naturally occurring biological control is well established. In mosquito breeding habitats, the importance and usefulness of biological control is just now becoming clearly established – witness several papers at this Annual Conference by Washino, Reeves, Legner, Bay, Garcia, among others.

From here on out, we must give increasing attention to the impact of chemicals used in mosquito control on beneficial forms in the treated habitat. This applies particularly to arthropod and fish predators of mosquitoes. Last May, Mulla (1970) discussed in considerable detail the impact of pesticides for mosquito control on these non-target organisms.

Resistance – All associated with mosquito control are aware of the problem posed by mosquito resistance to pesticide chemicals and the rather clear indication that the worst is yet to come. This may be the factor that finally not only conditions us to accept integrated control but forces us into it. The development of resistance to a pesticide is complex and depends on many factors. However, a most critical factor is how the pesticide is used and how much pesticide is used. In other words, how much selection pressure is put on the mosquito population. In an integrated control system, there is less risk of the development of resistance or it will develop more slowly than where there is a severe selection pressure under heavy pesticide use. This is the result of a lowered selection pressure in the integrated control system because pesticides are no longer responsible for virtually all of the mortality. Under integrated control the pesticide usage is directed against only relatively small portions of the population scattered in time and space. This minimizes selection pressure for resistance to pesticides. In the intervals between pesticide treatments, different kinds of selective pressures from other control procedures and from other elements of the environment will modify the large remaining population and may reduce trends toward resistance. The use of narrow-spectrum materials enhances this pattern and also avoids the development of resistance in other pest species associated with the target species.

Consider the Ecosystem: In integrated control systems, the complete environment – the complex of organisms (pests and nonpests, beneficial and indifferent species, etc.), man and his cultivated crops, and the conditioning physical environment – are considered together as a unit. Consideration of the ecosystem is the underlying philosophical approach to integrated control.

There have been examples where the agricultural use of pesticides applied without consideration of the total ecosystem has had an unfavorable impact on mosquito control. One example is the wide-scale and heavy use of insecticides for pests of cotton and other crops in Central America. Apparently, one side effect of this usage has been the development of resistance to DDT in anopheline mosquitoes and this resistance has greatly weakened the effectiveness of the Pan American Health Organization malaria eradication program. The cause and effect relationship here is not as well documented as one would like, but the available evidence seems very strong.

On the other hand, our California mosquito abatement districts have often been involved in control activities that have had undesirable effects in other parts of the agroecosystem in which they were operating. In the late forties and early fifties, a considerable portion of the DDT that we were finding in cow's milk had its origin in DDT treatments by the MAD's.

More recently an interesting situation has developed at the south end of Lake Tahoe (Dahlsten et al. 1969). Residential areas were fogged with malathion for several months in the summer to eliminate or reduce the pestiferous mountain *Aedes* and other mosquitoes. This has apparently resulted in severe outbreaks of two pine scales formerly rather rare. These are the pine needle scale, ***Phenacaspis pinifoliae***, and the black pine leaf scale, *Nuculaspis californica*. The infestations are very severe and some branches have been killed; however, the full implication of the outbreak is yet to be determined. What then is the tolerance level of a Tahoe resident for a mosquito population if he knows that the available mosquito control measure will result in the death of pine trees?

In conclusion, I say "I don't think we are ready for integrated control, but we had better start gearing up."

Acknowledgments

The manuscript for this paper was reviewed by my colleagues Deane P. Furman, Richard Garcia, Mir S. Mulla, Charles H. Schaefer, and R. van den Bosch, and they made many helpful suggestions for which I am grateful.

References Cited

Dahlsten, D.L., R. Garcia, J.E. Prine and R. Hunt. 1969. Insect problems in forest recreation areas. Calif. Agr. 23(7):4-6.

F.A.O. 1968. Report of the First Session of the FAO Panel of Experts on Integrated Pest Control. Rome, Sept. 18-22, 1967. PL/1967/M/7.

Mulla, Mir S. 1970. Integrated control of mosquitoes, chemical measures against pre-imaginal stages. Miscl. Publ., Entomol. Soc. Amer. (In press)

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.

1969. Evolving concepts of encephalitis prevention in California. Proc. Calif. Mosq. Control Assoc. 37:3-6.

Southwood, T.R.E. 1966. Ecological methods with particular reference to the study of insect populations. Methuen and Co. Ltd., London. 391 pp.

ARBOVIRUSES KNOWN TO OCCUR IN CALIFORNIA AND THEIR RELATIONSHIP TO DIFFERENT VECTORS AND VERTEBRATE HOSTS[1]

James L. Hardy, Ph.D.
University of California, School of Public Health
Berkeley

In most cases where adequate studies have been done, arboviruses have been found to be viruses of wildlife that are transmitted by hematophagous arthropods, including mosquitoes, ticks, sandflies, and biting midges. These viruses usually produce an inapparent infection in their wildlife hosts. Their importance to public health is the fact that they can and do produce disease in aberrant hosts, such as man and his domestic mammals, that accidently become involved in the transmission cycle. Tangential transmission of virus to man can occur when he enters an area where the viral transmission cycle is normally maintained or when he creates environments that support or augment the vectors and wildlife hosts of the virus. This latter point is best exemplified by the Central Valley of California where man has transformed a desert into rich agricultural lands and, in so doing, has greatly enhanced his exposure to the mosquito-borne viral encephalitides (Reeves and Hammon, 1962).

Information on arboviruses that are known to occur in California and on the arboviral research programs that are being conducted by the University of California at Berkeley was summarized before this group by Dr. W.C. Reeves in 1964 and 1965 (Reeves, 1964; Reeves, 1965). The purpose of this paper is to update our information on arboviruses of California and to briefly present what we have learned in the last 5 years about the vector-wildlife host relationships of arboviruses in Kern County.

Arboviruses in California and Their Association with Disease

At present 204 arboviruses have been registered in the "Catalogue of Arthropod-borne Viruses of the World" (Taylor, 1967). Fifteen of these viruses are known to occur in California, six of which are transmitted by mosquitoes, four by biting midges, and two by ticks (Table 1). Modoc, Rio Bravo, and Kern Canyon viruses have not been isolated from arthropods but are classified as arboviruses because they are similar in antigenic or biologic properties to proven arboviruses (W.H.O. 1967).

Six of the 15 viruses in California cause disease in man. Human infections of western equine encephalomyelitis (WEE), St. Louis encephalitis (SLE), and California encephalitis (CE) have been well documented (Reeves and Hammon, 1962). There has been one confirmed but not reported case of aseptic meningitis in a child due to infection with Modoc virus (Dr. W.C. Reeves, personal communication). Powassan virus has not been shown to infect man in California (unpublished data), and all known human infections with Rio Bravo virus have resulted from accidental infections in the laboratory (Sulkin et al., 1962).

WEE in horses and bluetongue disease in sheep have been confirmed on numerous occasions (Reeves and Hammon, 1962; McGowan and McKercher, 1954). Recently, our laboratory has been testing sera from undiagnosed cases of equine encephalomyelitis for hemagglutination-inhabiting (HI) antibodies to arboviruses other than WEE virus. These sera were kindly supplied by Dr. R.W. Emmons and Dr. E. H. Lennette of the California State Department of Public Health. Diagnostic rises in antibody titers have been demonstrated in several horses to SLE, Main Drain, or Turlock virus. It is unknown whether these viruses actually caused the disease. However, a serologic survey conducted in California during 1968 indicated that horses were frequently infected with these viruses (unpublished data).

WEE virus has also been isolated from the brains of sick or dead tree and ground squirrels sent to the California State Department of Public Health for rabies tests (Lennette et al., 1956). It remains to be determined, however, whether this virus actually causes disease in these animals. Experimental infection of wild birds and mammals has also demonstrated that WEE virus can produce a fatal infection in several species of wild birds, such as Whitecrowned Sparrows, Tricolored Blackbirds, and Red-winged Blackbirds (unpublished data).

Vectors and Wildlife Hosts of Arboviruses in Kern County

Studies in Kern County during the past five years have been directed toward learning what vectors and wildlife hosts are involved in the basic transmission cycles of 10 of the 13 arboviruses known to occur there (Reeves, 1964). The major criteria that have been used to establish these vector-wildlife host relationships are:

1. Evidence of natural infection by isolation of the virus from pools of nonengorged arthropods and from bloods or organs of vertebrates, by demonstration of high HI antibody prevalences to arboviruses in birds and mammals, or by frequent immunologic conversions in recaptured animals.
2. Demonstration of association between vectors and wildlife hosts by host preference studies (i.e., identification of blood meals and removal of ectoparasites from hosts).
3. Demonstration of temporal relationships between peak periods of viral activity and peak populations of vectors and susceptible hosts.
4. Susceptibility of suspected vectors and hosts to experimental infection.

The results of these studies are summarized in Table 2.

Viruses Transmitted by Mosquitoes

There is no question that *Culex tarsalis* Coq. is the primary vector and that wild birds are the primary amplifying hosts of WEE and SLE viruses during the summer encephal-

[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-SO1-FR 05441 from the National Institute of Health, U.S. Department of Health, Education and Welfare.

Table 1. Summary of arboviruses known to occur in California, January 1970.

Vector	Virus: Serogroup	Virus: Name	Source of viral isolations in California	Associated with disease: Man	Associated with disease: Domestic and wild mammals	References
Mosquito	A	WEE	*C. tarsalis*, other mosquitoes, mites, birds, rodents, an opossum, horses, and man	+	Horse, tree squirrels and ground squirrels	Johnson 1960 Lennette et al. 1956 Reeves & Hammon 1962 Emmons & Lennette 1969
	B	SLE	*C. tarsalis*, other mosquitoes, mites, birds, a gray fox, and man	+	Horse[1]	Reeves & Hammon 1962 Emmons & Lennette 1967
	California	CE	*A. melanimon*, and *C. tarsalis*	+		Hammon & Reeves 1952
		Jerry Slough	*C. inornata*	—		Taylor 1967
	Turlock	Turlock	*C. tarsalis*, other mosquitoes, Horn flies, and House finches	—	Horse[1]	Lennette et al. 1957 Taylor 1967
	Ungrouped	Hart Park	*C. tarsalis*, and birds	—		Taylor 1967
Tick	B	Powassan	Skunk	+[2]		Johnson, H.N. (Personal communication) McLean & Donohue 1959
	Ungrouped	CTF	*D. andersoni*, *D. variabilis* rodents, and man	+		Eklund et al., 1955 Emmons & Lennette 1966 Johnson, H.N. (Personal communication)
Biting midge	Bunyamwera	Lokern	*C. variipennis*, *C. tarsalis*. and leporids	—		Taylor 1967
		Main Drain	*C. variipennis* and leporids	—	Horse[1]	Taylor 1967
	Simbu	Buttonwillow	*C. variipennis* and leporids	—		Reeves et al. 1970
	Ungrouped	Bluetongue	Sheep	—	Sheep	McKercher et al. 1953
Unknown	B	Modoc	Deer mice	+		Johnson 1960 Reeves, W.C. (Personal communication)
		Rio Bravo	Bats	+[2]		Johnson 1962 Sulkin et al. 1962
	Ungrouped	Kern Canyon	Bats	—		Taylor 1967

[1] Demonstrated only by diagnostic rises in antibody titers.
[2] Not known to be associated with human disease in California.

itis season in California (Reeves and Hammon, 1962). The question that still remains unanswered is how these viruses, as well as other mosquito-borne viruses, overwinter in a temperate climate (Reeves, 1961).

During the past five years we have added little new data that would resolve this question for WEE virus. No WEE virus has been isolated from numerous pools of ticks and fleas collected off wild mammals. Serologic surveys of wild birds and mammals demonstrated that a high proportion of resident birds, primarily House Finches and House Sparrows, were infected whereas rodents were rarely infected. However, rodents must still be considered as potential overwintering hosts because WEE virus was isolated from two rodents collected during the winter in Kern County (Hardy et al., 1966). There is virologic and serologic evidence that leporids, primarily *Lepus californicus*, become infected with WEE virus during August and September. Thus, these mammals could serve as secondary amplifying hosts because *C. tarsalis* feeds on rabbits (Tempelis, 1964) and experimentally infected *L. californicus* circulates high levels of virus in their blood (unpublished data).

Activity of SLE virus as measured by isolation of virus from *C. tarsalis* and immunologic conversions in sentinel chickens was absent during the summers of 1964 through 1967. Thus, attempts to study the overwintering mechanism of this virus have been unrewarding. Antibody to SLE virus was found in sera from rodents and leporids, but the significance of these results is unknown because at least two

Table 2. Vectors and wildlife hosts of ten arboviruses studied intensively in Kern County, 1963-1968.[1]

Type of Vector	Virus	Vector	Wildlife hosts: Birds	Rodents	Leporids
Mosquito	WEE	*C. tarsalis*	++[2]	+	+
	SLE	*C. tarsalis*	++	+	+
	Turlock	*C. tarsalis*	++	0	0
	CE	*A. melanimon*	+	+	++
Tick	Powassan[3]	Tick?	0	++	+
Biting midge	Buttonwillow	*C. variipennis*	0	+	++
	Lokern	*C. variipennis*	0	0	++
	Main Drain	*C. variipennis*	0	0	++
Unknown	Modoc	None?	0	++	+
	Rio Bravo	None?	0	0	0

[1]Hart Park, Jerry Slough and Kern Canyon viruses also occur in Kern County but have not been studied.

[2]Degree of involvement: 0 = rare or none, + = occasional, and ++ = frequent.

[3]The presence of a Powassan-like virus has only been demonstrated by serologic tests.

other group B arboviruses (Modoc and Powassan) are also infecting wild mammals in Kern County (Hardy et al., 1966).

Turlock virus was isolated from one pool of *Culex peus* Speiser and numerous pools of *C. tarsalis* collected in Kern County since 1965. High prevalences of antibody have been demonstrated in only two resident species of bird (House Finches and House Sparrows). There was little or no serologic evidence that this virus infected wild mammals. Experimental infection of wild birds and mammals demonstrated that most birds could serve as a source of virus for arthropod vectors, whereas mammals were relatively poor hosts. Thus, the transmission cycle of Turlock, WEE and SLE viruses during the summer is quite similar in that *C. tarsalis* is the primary vector and wild birds are the primary amplifying hosts. The main ecologic differences between WEE, SLE, and Turlock viruses are that (1) WEE and SLE viruses have wider host ranges because both mammals and birds can serve as hosts, and (2) the transmission cycle of Turlock virus can be maintained in areas where the population of *C. tarsalis* is too low to support the transmission of either WEE or SLE virus (unpublished data).

No isolations of CE virus have been made in California since the virus was isolated from *C. tarsalis* and *Aedes melanimon* Dyar collected in Kern County during 1943 and 1944 (Hammon and Reeves, 1952). However, a serologic survey of man and wild mammals conducted in Kern County during 1963 demonstrated that CE virus or a virus antigenically related to CE virus was still present in Kern County (Gresikova et al., 1964). Further serologic surveys during the last five years indicated that leporids were frequently infected and that rodents and birds were occasionally infected with this virus. However, experimental infection of wild birds indicated that birds were refractory to infection with CE virus. Thus, the specificity of the HI substance in avian sera will have to be determined before the results of the serologic surveys with CE virus can be fully evaluated.

Two other mosquito-transmitted viruses were isolated originally in Kern County, but have not been studied because of a lack of suitable test systems. Hart Park virus was isolated from numerous pools of *C. tarsalis* and from the blood of birds collected from 1955 to 1961 in Kern County and other areas of California (Taylor, 1967). Jerry Slough virus, which is antigenically related to CE virus, was isolated from two pools of *Culiseta inornata* (Williston) collected in 1963 (Taylor, 1967).

Tick-transmitted Viruses

There is serologic evidence that Powassan virus or a closely related virus in infecting wild rodents, primarily *Citellus beecheyi* and *Ammospermophilus nelsoni*, in Kern County (Hardy et al., 1966). In other areas of North America this virus is maintained in nature by a tick-to-rodent-to-tick transmission cycle (McLean et al., 1964). Thus far, no group B arbovirus has been recovered from numerous ticks and blood collected from wild mammals in Kern County. However, Powassan virus was isolated recently from a spotted skunk, *Spilogale putorius*, collected in Sonoma County, California (Dr. H.N. Johnson, personal communication). This is the first isolation of Powassan virus in California.

Culicoides-transmitted Viruses

Three new arboviruses (Buttonwillow, Lokern, and Main Drain) have been isolated repeatedly from biting midges of the *Culicoides variipennis* (Coq.) complex and from the blood of leporids collected in Kern County from 1963 to 1968 (Reeves et al., 1970; Hardy et al., 1970; Taylor, 1967). The transmission cycles of these viruses during the spring and summer involve *C. variipennis* as the primary vector and *Lepus californicus* (blacktail jackrabbit) as the primary vertebrate host. Another leporid, *Sylvilagus audubon*i (desert cottontail) probably serves as a secondary vertebrate host. These transmission cycles are further indicated by the finding that *C. variipennis* feeds frequently on rabbits as well as domestic mammals (Dr. C.H. Tempelis, personal communication). However, little effort has been made to determine if mosquitoes that feed predominantly on mammals, including leporids (Tempelis, 1964), are involved in transmission of these viruses. The overwintering mechanism for *Culicoides*-transmitted viruses is also unknown.

Although bluetongue virus is transmitted by *C. variipennis* (Foster et al., 1968), no isolations of this virus have been made from *C. variipennis* collected in Kern County. However, we are not certain that our viral assay systems could detect bluetongue virus if it was present.

Other Viruses

As previously mentioned, there is no evidence that Modoc, Rio Bravo, and Kern Canyon viruses are transmitted by arthropods (Johnson, 1967). These viruses have been isolated only from tissues or organs of mammals (Taylor, 1967).

Modoc and Rio Bravo viruses are important because they produce chronic infections in their natural hosts (Constantine and Woodall, 1964; Johnson, 1967; Dr. H.N. Johnson, personal communication) and they are antigenically related to a proven arbovirus that occurs in California (i.e., SLE virus). This raises the question of whether arthropods are required for the survival of certain arboviruses. Certainly, the role of chronic infection in the maintenance of arboviruses needs to be investigated, as was previously mentioned by Reeves (1961).

Summary

Fifteen arboviruses occur in California. WEE, SLE, CE, Powassan, Modoc, and Rio Bravo viruses are associated with disease in man or domestic mammals, or both. There is serologic evidence that Turlock and Main Drain viruses might be associated with clinical disease in horses. WEE virus is thought to produce disease in certain species of wildlife.

Our knowledge is incomplete on what vectors and wildlife hosts are involved in the basic transmission cycles of mosquito-borne viruses. Viruses transmitted by biting midges appear to have a *C. variipennis*-to-blacktail jackrabbit cycle. Modoc and Rio Bravo viruses are apparently not transmitted by arthropods but are maintained as chronic infections in thier mammalian hosts.

References Cited

Constantine, D.G., and D.F. Woodall. 1964. Latent infection of Rio Bravo virus in salivary glands of bats. Pub. Health Rep. 79: 1033-1039.

Eklund, C.M., G.M. Kohls, and J.M. Brennan. 1955. Distribution of Colorado tick fever and virus-carrying ticks. J.A.M.A. 157: 335-337.

Emmons, R.W., and E.H. Lennett. 1966. Immunofluorescent staining in the laboratory diagnosis of Colorado tick fever. J. Lab. Clin. Med. 68:923-929.

1967. Isolation of St. Louis encephalitis virus from a naturally-infected gray fox *Urocyon cinereoargenteus*. Proc. Soc. Exp. Biol. and Med. 125:443-447.

1969. Isolation of western equine encephalomyelitis virus from an opossum. Science 163:945-946.

Foster, N.M., R.H. Jones, and A.J. Luedke. 1968. Transmission of attenuated and virulent bluetongue virus with *Culicoides variipennis* infected orally via sheep. Am. J. Vet. Res. 29: 275-279.

Gresikova, M., W.C. Reeves, and R.P. Scrivani. 1964. California encephalitis virus: an evaluation of its continued endemic states in Kern County, California. Am. J. Hyg. 80:229-234.

Hammon, W. McD., and W.C. Reeves. 1952. California encephalitis virus. A newly described agent. I. Evidence of natural infection in man and other animals. California Med. 77:303-309.

Hardy, J.L., W.C. Reeves, R.P. Scrivani, and D.R. Roberts. 1966. Wild mammals as hosts of arboviruses in Kern County, California. II. Serologic and virologic surveys. Zoonoses Res. In press.

Hardy, J.L., R.P. Scrivani, R.N. Lyness, R.L. Nelson, and D.R. Roberts. 1970. Ecologic studies on Buttonwillow virus in Kern County, California., 1961-1968. Am. J. Trop. Med. and Hyg. In press.

Johnson, H.N. 1960. Public health in relation to birds: arthropod-borne viruses. Trans. N.A. Wildl. Conf. 25:121-133.

1962. The Rio Bravo virus: Virus identified with group B arthropod-borne viruses by hemagglutination inhibition and complement fixation tests. Proc. Ninth Pacific Sci. Congress. 17:39.

1967. Ecological implications of antigenically related mammalian viruses for which arthropod vectors are unknown and avian associated soft tick viruses. Jap. J. Med. Sci. and Biol. 20: 160-166.

Lennette, E.H., M.I. Ota, M.E. Dobbs, and A.S. Browne. 1956. Isolation of western equine encephalomyelitis virus from naturally-infected squirrels in California. Am. J. Hyg. 64: 276-280.

Lennette, E.H., M.I. Ota, F.Y. Fujimoto, A. Wiener, and E.C. Loomis. 1957. Turlock virus: A presumably new arthropod-borne virus. Isolation and identification. Am. J. Trop. Med. and Hyg. 6:1024-1035.

McGowan, B., and D.G. McKercher. 1954. Studies on bluetongue. II. Field experiences with bluetongue in California. Proc. Am. Vet. Med. Assoc., p. 61-65.

McKercher, D.G., B. McGowan, and J.A. Howarth. 1953. A preliminary report on the isolation and identification of the bluetongue virus from sheep in California. J.A.V.M.A. 122:300-310.

McLean, D.M., and W.L. Donohue. 1959. Powassan virus: isolation of virus from a fatal case of encephalitis. Canad. M. Assoc. J. 80:708-711.

McLean, D.M., A. de Vos, and E.J. Quantz. 1964. Powassan virus: Field investigations during the summer of 1963. Am. J. Trop. Med. and Hyg. 13:747-753.

Reeves, W.C. 1961. Overwintering of arthropod-borne viruses. Progr. Med. Virol. 3:59-78.

1964. Newer developments in arthropod-borne viruses in California. Proc. Calif. Mosq. Control Assoc. 32:78-81.

1965. Developing balanced programs in the University of California for mosquito control-medical aspects. Proc. Calif. Mosq. Control Assoc. 33:46-49.

Reeves, W.C., and W. McD. Hammon. 1962. Epidemiology of the arthropod-borne viral encephalitides in Kern County, California, 1943-1952. Univ. of Calif. Pub. in Public Health, V. 4, Univ. of Calif. Press, Berkeley.

Reeves, W.C., R.P. Scrivani, J.L. Hardy, D.R. Roberts, and R.L. Nelson. 1970. Buttonwillow virus, a new arbovirus isolated from mammals and *Culicoides* midges in Kern County, California. Am. J. Trop. Med. and Hyg. In press.

Sulkin, S.E., K.F. Burns, D.F. Shelton, and C. Wallis. 1962. Bat salivary gland virus: Infections of man and monkeys. Texas Rep. Biol. Med. 20:113-127.

Taylor, R.M. (Compiler). 1967. Catalogue of Arthropod-borne Viruses of the World, ed. 1. Washington, D.C., U.S. Govt. Printing Officer, Publication No. 1760, 898 p.

Tempelis, C.H. 1964. Current knowledge of the feeding habits of California mosquitoes. Proc. Calif. Mosq. Control Assoc. 32: 39-42.

World Health Organization. 1967. Arboviruses and human disease. Report of a WHO Scientific group. Wld. Hlth. Org. Techn. Rep. Ser. 369:1-84.

SIGNIFICANT MOSQUITO CONTROL DEVELOPMENTS FROM THE 1969 CALIFORNIA ENCEPHALITIS EMERGENCY

Thomas D. Mulhern
Bureau of Vector Control and Solid Waste Management
California State Department of Public Health

Introduction

The principles employed in mosquito control have been re-stated many times. New terms and catch phrases are frequently coined, but we are still guided by the fundamental principles of mosquito source reduction (formerly called "permanent control"), naturalistic control (including biological control), and chemical control of mosquito larvae or adults. New instruments, devices, tools and chemicals have been introduced in the interest of greater efficacy or economy but there has been little change in fundamental approaches. Progress continues to be evolutionary rather than revolutionary.

1969 Problem

In 1969 precipitation over California in the form of rainfall and snowfall reached an all-time record, particularly over the southern Sierras which received up to 430% of normal snowpack. Extensive flooding of the southern San Joaquin Valley and lesser floods elsewhere in the state were predicted with certainty by the hydrographic computers to occur mainly in valley areas historically associated with encephalitis. Substantial increases in vector mosquito production were anticipated with consequent implications of a possible encephalitis epidemic if effective preventive measures were not employed. Accordingly, local state, and federal agencies collaborated in developing an emergency program of vector mosquito control which was executed as the most practicable means of averting or minimizing an epidemic. The unique feature of this program was that it was undertaken on the basis of the broadest possible scientific appraisal of the factors which contribute to encephalitis epidemics (e.g., Reeves 1967) and was funded and begun before infection of horses or humans was apparent and before viruses had been detected in vector, host, or reservoir species.

The plan included three phases:

Phase One – recognized local mosquito abatement agencies as the primary resource for mosquito control and encouraged these agencies to intensify their programs, in some cases extending beyond their boundaries. The territory of the local mosquito control agencies (Figure 1) comprises most of the Central Valley, which contains extensive areas which could produce mosquitoes in close proximity to large numbers of people. The aggregate area included within these local programs is about 40,000 square miles.

Table 1 from the 1970 Year Book of the California Mosquito Control Association gives for 1969, by local agencies, a summary of the insecticides applied by aircraft and acreages treated including applications made in connection with phase one of the emergency program.

Local agencies eligible for federal flood disaster assistance through the Federal Office of Emergency Preparedness were assisted in processing applications by the State Department of Public Health, the State Disaster Office, and the U.S. Public Health Service. Phase one also emphasized the importance of intensified surveillance to provide the best possible guidance to control operations, and a team from the U.S. Public Health Service made several intensive sweeps through the areas of concern collecting mosquitoes to be processed for virus detection. This was supplementary to the annual surveillance which is carried out in representative areas by the University of California and the California State Department of Public Health.

There are many smaller but nevertheless important mosquito sources occurring irregularly over some 20,000 square miles outside the boundaries of the local control agencies and these were the sources designated to receive primary attention in phase two.

Phase Two – provided limited capability to the State Department of Public Health to conduct a supplimentary "search and destroy" operation, primarily in areas not protected by local mosquito control programs. In some cases, the helicopters under contract to the State were employed upon request to perform needed services within the boundaries of local agencies, when equal local expenditures chargeable against federal emergency funding were offset by so doing.

Table 2 presents a summary of the areas sprayed by helicopter in connection with phase two of the emergency program. Of approximately 300,000 acres originally estimated as likely to require larviciding within this phase of the program, only 67,000 acres were sprayed. The reduction was attributed in part to extraordinary activity by mosquito fish and other predators in much of the flood waters which inundated hundreds of thousands of acres of farm lands and river flood plains. It was also possible through the use of helicopters to determine the limits of the infested areas and to restrict larviciding to these areas, and in most instances to those areas which were actually producing *Culex tarsalis*. Finally, procurement procedures delayed the beginning of the helicopter program for nearly a month, with contract machines not put in operation until July 5. Therefore, areas which might have been sprayed during this period were not treated.

Phase Three – was a reserve plan to be implemented only if an epidemic of encephalitis were to occur despite the preventive operations of phase one and phase two. Phase three would have included large scale aircraft adulticiding operations over both rural and urban areas to a possible maximum of 6 million acres. Fortunately, low virus levels combined with successful suppression of mosquitoes made phase three unnecessary.

In this emergency year, as is true for normal years, the primary operation and major expenditures were those of local mosquito control agencies. These programs provide

Table 1. Spraying performed by mosquito abatement districts in 1969.

	AGENCY OWNED & OPERATED AIRCRAFT													CONTRACTED AIRCRAFT		
	Number & Type of Aircraft							Hours Flown		Acres Treated		Cost per Acre		Acres Treated		Cost per Acre
AGENCY REPORTING	Piper 235	Call Air A9	Call Air A6	Call Air A5	Ag Cat 450	Bell Helicopter	Enstrom Helicopter	Liquid Formulations	Dry Formulations	Liquid Formulations	Dry Formulations	Excluding Insecticides		Liquid Formulations	Dry Formulations	Excluding Insecticides
COASTAL REGION																
Diablo Valley		-								-				26,965		.3435
Marin County			-	-										8,050		.372
Napa County		-								--				3,400	300	.278
N. Salinas Valley		--	1		-			100		6,022	--	1.41		120	-	2.50
Solano							-		-					29,100		.278
SACRAMENTO VY. REGION																
Butte					2			726		178,191		.2449				
Colusa														38,592	700	.123
Durham														2,150		.333
Glenn County														6,300		.35
Lake				–										515		.81
Sacramento Co.-Yolo Co.				--										39,223	27,540	.299
Shasta														1,050	5,614	.57
Sutter-Yuba														84,935		.22
Tehama														2,581	2,632	.421
N. SAN JOAQUIN REGION																
East Side	1						-	402		72,652		.29		5,910		.384
Merced County		3				1		1,053	-	251,634		.253				
N. San Joaquin Co.														1,820	90	1.53
San Joaquin	2						-	662	181	104,075	10,250	.33				
Turlock	1				--			545		86,194	-	.259		6,690		.16
S. SAN JOAQUIN REGION																
Consolidated	-	2	--	-				710		108,293		.40				
Delano	--							–						3,880		.30
Delta	1	-	--	-				453		97,321	–	.172		38,038	2,137	.34
Fresno Westside	–	2				—	-	588	9	118,394	2,460	.30			--	-
Kern	1	1						402	41	179,557	14,613	.1202		31,728	34,810	.2087
Kings	4							1,642		293,944	-			24,405		-
Madera	–	-												27,588	27,219	.37
Tulare	1		-	1			1	958	-	168,585		.147				
West Side	—		--	-			-				-			18,538	2,462	.476
S. CALIFORNIA REGION																
Coachella Valley	--	-	-		--							-		80	15	1.42
Inyo County H. D.											-	-		21,000		.71
Northwest									-	–	—	-		5,410	-	.30
TOTALS	11	8	1	1	2	1	1	8,241	231	1,664,862	27,323			428,068	103,519	

Table 2. Spraying performed under Phase Two of emergency program, by aircraft under contract to California State Department of Public Health.

SEASON SUMMARY 1969
AIRCRAFT PERFORMANCE RECORDS

Aircraft		County and Location	Aircraft Time Ferry	Aircraft Time Spot Spray	Aircraft Time Area Spray	Aircraft Time Total	Acres Sprayed	Insecticide Gallons	Insecticide Pounds
N 8529F	Bell	Shasta – Tehama – Etc.	6.3	28.5	4.0	38.8	2,721	77.2	77.2
N 988B	Bell	Shasta – Tehama – Etc.	2.4	7.0	–	9.4	–	–	–
N 1329X	Bell	Shasta – Tehama – Etc.	3.5	4.5	11.0	19.0	1,412	70.5	70.8
N 9995C*	Cal Air A5	Shasta – Tehama – Modoc	–	–	–	23.0	4,825	590.0	250.0
179B	Bell	Sacramento Area	34.3	76.9	47.3	158.6	19,128	529.8	592.3
N 65132*	Pawnee	Sacramento Area	4.7	–	43.0	47.7	17,040	763.5	804.0
2488B	Bell	Merced – Etc.	6.7	13.0	2.1	21.8	605	30.0	30.0
N 4742R	Bell	Merced – Kern	81.3	71.1	47.8	200.2	16,822	1,179.7	1,354.45
N 90476	Hiller	Inyo – Etc.	20.9	62.3	21.7	104.9	5,000	313.0	526.8
		TOTAL	178.3	263.3	176.9	623.4	67,553	3,552.9	3,705.6

*Fixed Wing Aircraft

mosquito control services to more than 40,000 square miles at an annual cost of nearly $9 million. The 63 agencies normally apply insecticides over about 1.5 million acres, in addition to providing other mosquito control services. In 1969 the totals approached $10 million and 2½ million acres. Some of the agencies received federal flood disaster funds to offset a portion of the added costs.

The Governor of California authorized the use of state funds up to $500,000 to support phase two of the emergency program. Approximately one-half of this amount was expended in the surveillance-control operation during which 67,000 acres of mosquito sources were sprayed. This was largely limited to areas outside local mosquito control agencies, with limited services provided on request within local jurisdictions. A portion of the costs will be reimbursed through federal flood emergency funds administered by the U.S. Office of Emergency Preparedness.

This is not intended to be a comprehensive report of the emergency program, but merely to comment upon the "new" or significant aspects:

A. The experience of the past year indicates that however successful an "emergency" program may be, it is no substitute for a well-organized, continuing, stable, local program. The people who live in "unprotected" areas where there is a significant problem should thus be encouraged to join or establish a local program.

B. The problem varied greatly from area to area. Some agencies experienced only normal or even subnormal problems, as reflected in the areas treated with insecticides. Conversely, agencies located in major flood areas (notably Delta, Tulare, and Kern mosquito abatement districts) report increases in areas sprayed in the order of 200% to 300%. The manager of one agency which has a very high proportion of problem area in relation to available money, manpower, and other resources reported: "Situation normal – we had an emergency such as we experience every year." The 31 agencies responding to a questionnaire indicated that the area sprayed in 1969 was 41% greater than in 1968.

C. The low volume spray application technique was employed much more extensively in 1969, in fact the entire phase two airspray operation consisted of low volume application of Dursban® and fenthion.

Experience with low volume sprays in California and elsewhere indicates that when meterological conditions are ideal and the mosquitoes are highly susceptible to the toxicant, high levels of control can be achieved with as little as 1 fl oz/acre, given dispersal systems which produce very fine droplets. In planning for phase two it was apparent that operations would frequently be necessary when spray conditions were far from ideal (high temperatures, low humidity, turbulent air, winds up to 8 mph, etc.), and a fine droplet spray was contraindicated. Accordingly, since somewhat larger droplets and somewhat larger volumes of spray had given good results under difficult meterological conditions in the "HI–LO" tests of October 1967 (Mulhern et al. 1968), a somewhat arbitrary decision was made to employ similar parameters. P400 polypropylene glycol was suggested by Harold Lembright of Dow Chemical Company as a nonvolatile diluent or extender, and the application rates were set at 6 oz/acre for larviciding and 3 oz/acre for adulticiding. Nozzles and pressures were selected to give larger droplets for larviciding than for adulticiding. For larviciding it was desired that 80% of the volume of spray be in droplets within a range of 50-300 microns diameter, and for adulticiding 80% of the volume of spray was to be in droplets within a size range of 50-100 microns. With the relatively high viscocity P400 formulation, the equipment produced somewhat larger droplets than planned; however, the applications were highly successful in all cases except where mosquito populations were shown to be resistant.

Meterological conditions are frequently unfavorable for airspraying in the Central Valley of California during the mosquito season. For example, the Butte County Mosquito Abatement District kept a log for one complete season during which there were only 20 out of 126 days when scheduled spray operations were completed without serious meterological interference.

D. Helicopters were employed extensively in phase two, extending the survey capability of entomologists by 5 to 10 times compared with the area which could have been surveyed using ground vehicles. Each helicopter could carry two entomologists when intensive inspection was required, but normally one was sufficient. It is estimated that each of these inspectors averaged more than 20 sq mi per hour, examining the area with sufficient care to determine whether spraying was necessary. This method also permitted access to areas which could not have been reached by any other means. All helicopters were equipped with low volume spray equipment to allow immediate treatments when indicated.

E. The first surveillance mission by helicopter was performed in March over eastern Madera and Merced counties, areas characterized by many low places (pot holes) which hold water in the spring months. While these pools had shown high populations of larvae when examined in March and April of 1967, the 1969 inspections revealed that the same pools were well stocked with predators and most of them were free of mosquitoes. Thus, alerted to an extraordinary biological control activity which appeared to be taking place, subsequent search missions included field appraisal of naturalistic control. Inspection of the flooded lands along the Kings and San Joaquin rivers, in the Owens Valley, and in the flooded lands bordering the Tulare Lake also strongly suggested that natural forces were minimizing mosquito production. In the latter instances, high populations of mosquito fish were noted where larvae were absent. Thousands of acres were thus eliminated from the spray program. Areas which did not have high populations of mosquito fish and other predators generally required spraying.

F. One major spray application performed in Kings County with Dursban against *C. tarsalis* failed. This mosquito population has since then been found to be highly resistant to all of the organophosphorus materials tested.

The impression should not be given that all of the mosquito sources were found or that all which were found were treated. High populations of *C. tarsalis* adults were observed in a considerable number of the more remote uncontrolled areas and some of the smaller residential communities also exhibited high counts at t mes. However, populations in most of the larger communities were generally moderate, owing to the efforts of mosquito control forces. It is also believed that the dry weather which prevailed following the spring rains helped to shorten the life span of those mosquitoes which did emerge.

Other papers presented at this meeting have emphasized the unexplained enigma of the season. Conditions appeared ideal for record production of the vector mosquitoes in many areas, yet very few virus recoveries were made from the large numbers of mosquito pools processed in the laboratories. Only five human cases of encephalitis were confirmed – all St. Louis and all in the Sacramento Valley.

The 1969 emergency operation represented an excellent example of cooperation between local mosquito control agencies, local health departments, the University of California, the State Department of Public Health, the State Disaster Office, the California National Guard, the U.S. Public Health Service, the Federal Office of Emergency Preparedness, and the various commercial suppliers and contractors.

References Cited

Mulhern, Thomas D. (Moderator). 1968. Panel: Very low volume spraying for mosquito control. Proc. Calif. Mosq. Control Assoc. 36:10-17.

Reeves, William C. 1967. Factors that influence the probability of epidemics of western equine, St. Louis, and California encephalitis in California. Calif. Vector Views 14(2):13-18.

MOSQUITO CONTROL AGENCIES

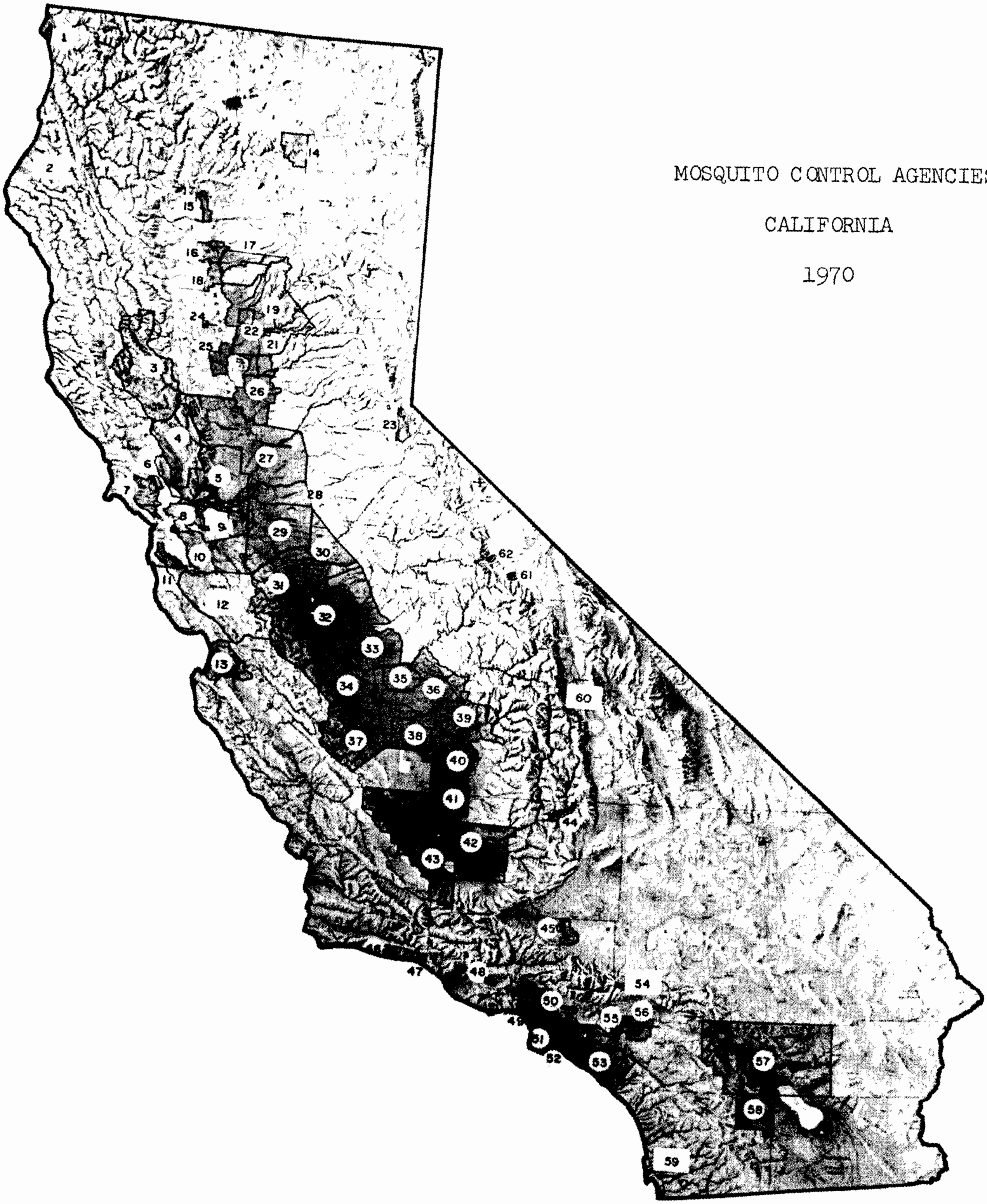
1. Del Norte County Flood Control District
2. Humboldt-Del Norte County Health Department
3. Lake County MAD
4. Napa County MAD
5. Solano County MAD
6. Sonoma MAD
7. Marin County MAD
8. Contra Costa MAD
9. Diablo Valley MAD
10. Alameda County MAD
11. San Mateo County MAD
12. San Clara County Health Department
13. Northern Salinas Valley MAD
14. Pine Grove MAD
15. Shasta MAD
16. Tehama County MAD
17. Los Molinos MAD
18. Corning MAD
19. Butte County MAD
20. Sheridan MAD
21. Oroville MAD
22. Durham MAD
23. El Dorado County Service Area No. 3
24. Glenn County MAD
25. Colusa MAD
26. Sutter-Yuba MAD
27. Sacramento County–Yolo County MAD
28. Northern San Joaquin County MAD
29. San Joaquin MAD
30. East Side MAD
31. Turlock MAD
32. Merced County MAD
33. Madera County MAD
34. Fresno Westside MAD
35. Fresno MAD
36. Consolidated MAD
37. Coalinga–Huron MAD
38. Kings MAD
39. Delta MAD
40. Tulare MAD
41. Delano MAD
42. Kern MAD
43. West Side MAD
44. South Fork MAD
45. Antelope Valley MAD
46. Goleta Valley MAD
47. Carpinteria Pest Abatement District
48. Moorpark MAD
49. Los Angeles County West MAD
50. Southeast MAD
51. Compton Creek MAD
52. Long Beach City Health Department
53. Orange County MAD
54. San Bernardino County Health Department
55. Northwest MAD
56. Riverside City Public Service Dept.
57. Coachella Valley MAD
58. Borrego Valley MAD
59. San Diego County Dept. of Public Health
60. Inyo County Health Department
61. Mammoth Lakes MAD
62. June Lake Loop MAD
63. Amador County Mosquito Control*

*Not shown on map.

MOSQUITO CONTROL AGENCIES

CALIFORNIA

1970



VECTOR CONTROL TRENDS OF THE PACIFIC NORTHWEST

John C. Stoner
Lane County Department of Health and Sanitation
Eugene, Oregon

Inasmuch as mosquito control in the Pacific Northwest came into existence in most of the region as a result of public health emphasis on the *Culex* mosquito to control western equine encephalitis in both horses and man, much of the work and associated programs are as yet public health oriented and directed toward the control of all vectors. The more affluent society of today, however, is demanding more and more the control of the mosquito primarily as a biting nuisance. This demand is slowly changing the nature of our programing and removing it from the usual "emergency" funding category and limited budget, and placing it in a priority recognized by budgeting as a necessity for welfare as well as health.

In Oregon during 1969 two new countywide districts were approved by voters, funded, and put in operation. Idaho now has four operating districts and one city-county district. In those areas throughout the Pacific Northwest where mosquito or vector control districts do not exist it is the responsibility of the public health sanitarian to keep himself qualified and knowledgeable of good mosquito control practices in order to advise generally and respond in emergencies. This is carried out by the Northwest Mosquito and Vector Control Association in its educational conference and the several state boards of health in their continuing education programs.

In spite of increased control efforts in the Pacific Northwest, western equine encephalitis was prevalent in the horses of all three states, twenty cases in Washington, forty-eight cases in Oregon, fifty cases in Idaho. Two confirmed cases of western equine encephalitis in humans in Oregon (on the tail end of the outbreak in horses) – two human cases of St. Louis encephalitis were reported in Idaho. Mosquito pools collected in Oregon during the horse outbreak were approximately 18% positive for western equine encephalitis (20 of 109). The species identified in these pools were *C. tarsalis*, *C. pipiens*, and *Culiseta inornata.*

Tourism and recreation in the Pacific Northwest is still classified as the third largest industry. The opening of wilderness areas to the public is bringing with it a demand to control the mosquitoes to allow the use of these areas. Biting counts taken in the Waldo Lake area during a feasibility study for control were 70 – 100 per minute at one site and 40 per minute in another. The adults collected in this sample were almost exclusively *Aedes communis.* Cooperative financing for control activities (by the facility developing agency) in most instances has not been forthcoming, and as a result many vacations are cut short for lack of finances to institute control. Estimated cost by this Department to control mosquitoes at Waldo Lake for eight weeks is $4,415, broken down between 226 campsites now existing, the cost per site per day would be $ .27. Is this too high a cost for comfort?

Biological control through use of the mosquito fish (*Gambusia affinis*) is promoted whenever possible with many districts and departments having stock available for private ponds or sloughs, thereby supplementing their own stocking effort. Sawmilling practices have changed to a large degree in the Northwest by substituting "dry decks" and stacking machinery for the old log ponds which in years past consumed high portions of mosquito control budgets.

Chemical control is still the greater part of budget expenditures, however, with more and more effort in the field of LV application and granular material. As elsewhere, DDT is being attacked and banned, either statewide or as in Idaho, banned in the City of Boise as of January 1970. In Oregon, Governor McCall said, "the ban in Oregon would mean no use of DDT except where there is no safe alternative, and then only for protecting the health, food sources, natural resources and general welfare of our citizens." Development of resistance to insecticides in the Pacific Northwest has been slow and for the most part nonexistent (DDT on several occasions). This is due apparently to the relatively short exposure to insecticide during the short mosquito season and limited number of generations produced in this short period of time.

The ticks still remain as an important vector of several diseases. *Dermacentor andersoni*, prevalent in the country located east of the Cascade Range of mountains, is responsible for Rocky Mountain spotted fever and Colorado tick fever. In Oregon 10 C.T.F. positive pools of ticks were collected in Lake, Klamath and Baker counties. Idaho reported three cases of relapsing fever.

Musca autumnalis, the face fly, was for several years an important vector in the Pacific Northwest, as well as being new to the region. Of economic importance as well as a nuisance it is responsible for the spread of pinkeye in cattle, causing temporary and even permanent blindness. Reports from the field indicate widespread populations at the present time, but a significant reduction in numbers compared to the initial infestation in the region.

Recent environmental surveys being conducted in Lane County, Oregon, record vector harborage areas on each parcel of ground investigated. The properties are investigated for both arthropods and rodents. This information is being stored on computer tape with other environmental data which will be translated by computer-digitizer to maps. We feel this computerized programing will be invaluable in solving many of our vector problems in Lane County. This particular program is being made possible by three federal agency grants which will assist Lane County in creating a County General Plan, a County Water Pollution Abatement Plan and Rural Water and Sewerage System Plan. Surveys to date in urban and suburban areas of Lane County indicate harborage areas on 25 – 80% of the properties investigated. We are hopeful that the use of the computer and the collected data during the next several years will lead to reduced costs and better control of the vectors we harbor in the Pacific Northwest.

REVIEW OF MOSQUITO AND OTHER VECTOR CONTROL ACTIVITIES IN UTAH DURING 1969

Don M. Rees[1] and Glen C. Collett[2]

About eighty percent of the population of Utah now resides within the boundaries of mosquito abatement districts. This has been accomplished since the enabling legislation was passed in Utah in 1923 and the Salt Lake City Mosquito Abatement District organized in 1924. There are ten organized districts in Utah located in seven counties. Nine of these are operating under the legislation enacted in 1923 and one through a county commission. Small sporadic mosquito control programs are conducted in other counties in Utah when the need is urgent and funds available.

The Utah Mosquito Abatement Association and the Mosquito Control – Fish and Wildlife Coordination Committee continue to function as influential organizations for promoting mosquito control and the propagation and management of wildlife.

The twenty-second annual meeting of the Utah Mosquito Abatement Association was held in Brigham City, Utah, October 6-7, 1969, with the Box Elder County Mosquito and Fly Abatement District serving as host. Speakers from California, Colorado, Idaho and Louisiana contributed much to the success of the conference. We extend an invitation to you to attend our next annual meeting which will be held in Provo, Utah, on October 5-6, 1970.

From available information, based on annual reports, mosquito control problems during 1969 were greater than usual in Utah. Since the 1958 encephalitis outbreak in Utah, the Salt Lake City and South Salt Lake County mosquito abatement districts have assumed the responsibility of developing and maintaining a surveillance program on encephalitis in the area. This has been based primarily on the fluctuation of the annual populations of *Culex tarsalis* and climatic factors affecting these populations. In addition for the past seven years sentinel chicken flocks have been maintained in the Salt Lake City area by the Arboviral Disease Section of NCDC in Fort Collins to obtain information pertaining to encephalitis transmission to these flocks.

Weather conditions early in 1969 were favorable for a high *C. tarsalis* population. Runoff in Salt Lake County was predicted at 132% of normal with temperatures for May well above normal. These factors caused considerable concern that a serious encephalitis and mosquito annoyance might develop. As a result the Arboviral Disease Section of NCDC agreed to test pools of *C. tarsalis* for virus activity. Weekly collections were sent to them from June to September.

Weather conditions drastically changed during the last half of June with above normal precipitation and below normal temperatures and these conditions continued through July. The *C. tarsalis* population during the remainder of the season declined well below the previous five-year average.

[1]Center for Environmental Biology, University of Utah, Salt Lake City, Utah.

[2]Salt Lake City Mosquito Abatement District, Salt Lake City, Utah.

The sentinel chicken flocks were bled October 20, and the report from Fort Collins indicated one positive for St. Louis encephalitis from the flock west of Salt Lake City. No positive isolations were reported from pools of *C. tarsalis* which were sent in weekly.

As a result of reported annoyance from the biting gnat, *Leptoconops kerteszi* Kieffer, received from many parts of the state, an application for funds to support a study of this gnat in Utah was submitted by Dr. Don M. Rees to the United States Army Research and Development Command. The application was approved and funds awarded by this agency for a two-year study, beginning March 1, 1969. This study is in progress.

The Great Salt Lake State Park was opened for visitors in May of 1969. As a result of the great number of adult brine flies, family Ephydridae, present and the abundance of pupal skins that accumulate along the shoreline of the lake, those visiting the park complained about these annoying conditions. The Governor of the State called a meeting on August 13 of individuals from various state and local government agencies, universities, industry, and civic organizations for the purpose of determining what could be done to cope with the problem. A committee was organized for the purpose of determining a plan for study and control of this fly. This committee has applied for federal funds in order to adequately study this problem and make control recommendations. Dr. Don M. Rees and Jay E. Graham were included on the committee.

The snipe fly *(Symphoromyia)* was abundant and annoying on the golf courses and recreational areas in the canyons east of Salt Lake County. At the request of the Salt Lake City Parks Department some adulticiding was done for the abatement of this biting fly.

The Community Studies on Pesticides being conducted by the Utah State Division of Health completed its third year of investigation. The objective of this study is "to determine the type and degree of pesticide exposure which the human population experiences, the ecological factors affecting this exposure and the characteristics of the subject population." Included in the study of the exposed group are several employees of the mosquito abatement districts in Salt Lake County. In the annual physical and the three quarterly follow-up examinations given each participant, no obvious differences could be detected in the health of the exposed versus the unexposed groups. Subtle differences are being carefully investigated.

In addition to the mosquito control workers participating in the pesticide study, cholinesterase levels were monitored on all mosquito control employees in Salt Lake County during peak periods of exposure to organophosphates. The cholinesterase level of two workers in a group of 15 became sufficiently low that discontinuance of exposure was recommended by the health officer. This advice was followed immediately and as a result increase in cholinesterase occurred in these two employees.

A Seminar on Pesticides and Public Health will be conducted in Salt Lake City February 4-5, 1970. This meeting is sponsored by the Utah Division of Health and the NCDC, Division of Community Studies, Atlanta, Georgia.

In addition to those mentioned, numerous research activities are being conducted by various investigators in the universities and in the mosquito abatement districts. It is recognized in Utah that research is an essential part of an effective mosquito control program.

CURRENT STATUS OF MOSQUITO CONTROL IN NEW JERSEY[1]

D. J. Sutherland and B. B. Pepper
Rutgers University
Camden, New Jersey

For a discussion of the status of mosquito control in New Jersey, it is necessary to review briefly the general types of mosquito problems we encounter. The State can be divided diagonally along geological lines into three regions: (1) the rolling rural area in the northwest, (2) the coastal plains region in the southeast with its perimeter of salt marsh, and (3) the heavily urbanized area between. While the northwestern part of the State is largely agricultural in nature, summer recreational activities around the many small lakes have been responsible for an increasing demand for mosquito control; woodland pool and flood water *Aedes* represent the major problems. The transitional region is rapidly becoming a part of the megalopolis that extends across the northeast. Although the flood plains of the Passaic and Hackensack River still produce an occasional brood of *Aedes vexans*, the major problem in this area stems from the house mosquito, *Culex pipiens*. Water pollution at every level has aggravated the situation to the point that even these two major rivers breed *C. pipiens* along their banks. The coastal plains region includes the coastal resort areas, agricultural lands, 250,000 acres of tidal salt marshes, as well as cedar bogs and pine barrens. The major nuisance problem is the salt-marsh mosquito *Aedes sollicitans*, the control of which is highly important to the resort industry. The inland cedar bog and pine-barren areas appear to be the focal areas for eastern viral encephalitis and the mosquito vector associated with the bird cycle, *Culiseta melanura*.

Mosquito control is the immediate concern of the 20 active county mosquito extermination commissions (out of 21 counties); their activities, together with those of the State Mosquito Control Commission and those of municipalities surpasses the expenditure of $5 million/year. The State Mosquito Control Commission continues to increase its support of regional projects, thereby permitting the counties to work together on major drainage problems or where the multiple interests of conservation and urban development overlap.

It has been estimated that 60 – 70% of mosquito control efforts in New Jersey are directed toward source reduction through water management, a philosophy which we discussed at your 1967 meetings. Water management allows for multiple-purpose projects, which satisfy not only our interests but also those of conservation and wildlife. Involvement of representatives of these latter interests in mosquito control makes control an "easier" job. We even involve such representatives in consideration of the State Airspray Program as well as field evaluation of newer insecticides.

Although the majority of control effort is directed towards water management, we still are forced to utilize adulticides and larvicides. Currently malathion is used exclusively for adulticiding both by ground and aerial application, while Abate® and Baytex® prove to be valuable as larvicides. Until this year the choice of chemicals has included DDT since it still remains efficient and the most economical under our conditions. Resistance studies, continuing since 1960, indicate that selected resistance to this chemical is not prevalent but isolated to a few collections from the southern part of the State. Nevertheless, during the past few years, while still recommended by the New Jersey Agricultural Experiment Station and the County Mosquito Commission, its actual use has diminished largely due to public concern. DDT and its value as a pre-hatch treatment for flood water *Aedes* and as a residual barrier in adulticiding is still recognized and possible legislation in the immediate future is of great concern to mosquito control personnel.

In November, 1969 the Pesticide Regulation Division, Department of Agriculture (Federal Register, Vol. 34, No. 226 – Tuesday, November 25, 1969) announced the cancellation of registration for DDT use "in aquatic environments, marshes, wetlands, and adjacent areas except those which are essential for the control of disease vectors as determined by public health officials." For further consideration of this and other restrictive proposals, 90 days were allowed; the eventual outcome therefore is unknown at this time.

Federal concern of pesticides has stimulated state officials of New Jersey to consider the question also. Accordingly the Governor by Executive Order No. 58, August 11, 1969 established a 9-member Pesticide Council, headed by the State Secretary of Agriculture. Members included representatives of State Departments, legislators, and interested citizens. Similarly an advisory committee to the Council was established. The objective of the Council is to determine what insecticides are essential and where. Public hearings have been held, and, after January 19, 1970, 30 days will be allowed for rebuttal or additional testimony. In the interim, the New Jersey Experiment Station has removed DDT from all published recommendations of the Station. At this writing, mosquito control personnel in the

[1]Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology and Economic Zoology.

State await the recommendations of the Pesticide Council and eventual action by the State. However, mosquito control in New Jersey has been under regulation for many years (e.g., budget approval) and with little evidence of major damage to the environment and no legal suits pending relative to the improper use of pesticides in mosquito control, we have urged that certain insecticides continue to be permissible as residual adulticides.

Our desire to maintain DDT as a special residual adulticide is based largely on the public health problem of encephalitis. Research over the last decade indicates that a complex of mosquito species is probably involved and that it is important to control the older adult mosquitoes especially in the recreational wooded areas which are increasingly being invaded by campers and vacationers. The number of virus isolations from small animals in such areas is increasing. After evidence of encephalitis in 1968 (113 horses and 12 people), even a more serious situation was anticipated for 1969. This did not materialize, and, while rainfall and temperature may have been influential, the absence of an outbreak cannot be exactly attributed to any one factor. Although such predictions are so fallible, we are wary of 1970 since after the outbreak in 1968 new broods of birds and small animals with no immunity will be present and there is expected to be lethargy toward the need for equine immunization.

One of our continuing interests with reference to encephalitis is research dealing with host preference of the various mosquito species in the State, which will ultimately aid in the documentation of the disease-vector relationship.

In addition to encephalitis, our researchers are increasingly interested in mosquito-borne filarial parasites. Dog heartworm is a serious problem, particularly in coastal areas of southern New Jersey. Laboratory transmission studies indicate that *A. sollicitans*, our common salt-marsh mosquito, is the major vector of the infection in the southern portion of the State. Within the past year, attention has shifted to a newly discovered filarial parasite of the bullfrog. A state-wide survey revealed that nearly 50% of New Jersey bullfrogs circulate microfilariae of the filarid worm in the genus *Foleyella*. The parasite has been shown to develop to the infective stage in *Culex territans*, a mosquito known to feed primarily on cold-blooded animals. At the present time, infected frogs are maintained the year-round in our laboratories and the vector has been colonized. Information applicable to filarial parasites in general may be derived from this model system.

Other research includes studies on the subtle and extreme variations in the water quality throughout the State and how this not only influences the species of mosquito present but also wildlife. It is readily recognized that insecticides, their formulation and their field efficiency is greatly influenced by factors of water quality. In connection with formulations, we believe that one of the greatest areas needing research is here. All realize that much more insecticide is placed in the environment than is required to contact and kill the insect. While granulars do succeed in getting the insecticide closer to the larvae, efficient release (such as that of Abate from sand, as indicated in our present studies) is necessary and important.

Many researchers support new intense research on the aquatic environment and how mosquito control chemicals react in and affect fresh water, estuarine and marine environments and the various organisms they support. Such research should include not only personnel closely associated with such control activities but also representatives of other disciplines such as ecologists, microbiologists, etc.

Our research interests lie also in other areas but as is often the case actual progress is slow due to insufficient funding and does not match the intensity of the interest. In the case of equipment for water management and insecticide application, the development of the former, as evidenced by amphibious cranes and continuous excavation equipment has been rewarding. Research in application equipment especially, in ULV area, has been fragmentary, and this is but one important reason for our attendance at meetings such as this, that is, to learn of the advancements in other parts of the country and to adapt them where practical to the New Jersey mosquito control program.

CURRENT STATUS OF MOSQUITO CONTROL IN THE GULF COAST AREA

George T. Carmichael
New Orleans Mosquito Control District
New Orleans, Louisiana

To sum up what is new in mosquito control in Louisiana, one might almost say "everything". Only about 5 years ago there were no mosquito control programs in the state. Now there are 5, all centered in and around the metropolitan New Orleans area. The total sum of the budgets of these 5 districts in 1970 is about $1.3 million.

Permanent control (source reduction) is stressed by all districts and there is a considerable variety of projects and equipment. The amphibian dragline has proved to be a convenient and effective tool on the large marshes which surround New Orleans. About one-third of all the marshland in the United States is in southern Louisiana.

Inside the New Orleans city limits one permanent control project is in the formative stage. There are 8,000 acres of marsh in this project. The area is completely surrounded by levees, so there is no tidal effect. There is extensive mosquito production from one end to the other. The property is owned by New Orleans East, a development company.

Mosquito control fills the role of quarterback for this project, recruiting the cooperation and aid of many different agencies. By surveying the area we found that about 3,000 acres were a little higher, one to two feet, than the other 5,000 acres, so a levee was built through the middle, separating the higher land from the lower area. The 3,000 higher acres are to be dewatered and a pump will be used to maintain a permanent water level on the 5,000 acres. New Orleans East volunteered to provide a pumping station. The New Orleans Levee Board agreed to remove ineffective tidegates and install water control structures. The New Orleans Sewage and Water Board agreed to maintain the pumping station. The New Orleans Public Service agreed to install power lines to operate the pump. I believe this may prove to be the largest permanent mosquito control project that has been undertaken at one time.

As temporary control measures, the districts use both ground and aerial larviciding and adulticiding. We operate under the principle of not using the organic insecticides against larvae in order to maintain maximum susceptibility in the adults to the organic insecticides which we use as adulticides. Larviciding materials are mainly oils with surfactants, Flit® MLO and Paris green granules. For adulticiding our main materials are Dibrom®, malathion and Baytex®. Most districts use thermal fog but three districts have constructed ground ULV equipment and are impressed by the good results. They have used Dibrom at between ¼ and ½ oz per acre.

The mosquito control districts in the metro-New Orleans area use large amounts of ULV by air. These 5 districts have 4 small aircraft (2 Piper PA 18's, 1 Cessna Agwagon and a Grumman Ag Cat). The New Orleans District also has a DC3 equipped for aerial ULV. Helicopters are used for inspection in several of the districts.

Hurricane Camille struck the Mississippi Gulf coast, causing unbelievable devastation. There were approximately 150 human deaths. We offered our services to the area, and with support from the Office of Emergency Planning used our DC3 on a fly control program. About 6,000 gallons of Dibrom were used at 1¾ oz per acre, flying about 105 hrs. Reports indicated that the fly density in the debris was probably lower than it was inside the city of New Orleans at the same time. The flies were never out of control, although included in the destruction and resultant debris were a food factory and all its contents, 6 frozen food warehouses with tons of frozen seafood, and human and animal bodies.

The ULV system on the DC3 has two 120 gallon Fiberglas® tanks, an Oberdoffer pump powered by an electric motor, and a boom under each wing, each having 3 nozzles. The nozzles are D8's without cores, positioned 45° into the wind. There is a complete breakup of the spray material. The droplets average about 20 microns diameter, with only a few as large as 50 microns. The material is not detectable on the dye cards, and it is not detectable to a person under the plane. Unique features of the system are that it operates at night, at altitude 500 feet and with a 1,000 feet swath width.

In tests at New Orleans, 2 oz of malathion released at 500 ft altitude in 1,000 ft swaths produced virtually 100% mortality of cages mosquitoes. Almost of all the adult mosquitoes in this 18,000 acre experimental application were killed.

The New Orleans MAD and its personnel were subjected to a trying experience last year. A nationally publicized trial resulted from the death of Jayne Mansfield, in which the district was sued for $8.7 million. There were 21 attorneys involved in the lawsuit and we were tied up in the proceedings for about 6 weeks during the fall of 1969. I am happy to say that we won the jury trial and our personnel were acquitted on the charge of contributing through negligence to the cause of the accident.

Louisiana recently established a state vector control unit of the State Board of Health. This is patterned after the plan employed in California.

I had the opportunity to meet with NASA officials in the Manned Space Center, Houston, Texas, where there is an Earth Resources Division. That agency has been using multiple exposure photography in many different fields of value to geologists, agriculturists, etc. There is a possibility that the techniques might work for mosquito control surveys. The personnel at NASA showed us some of the pictures that were taken from Apollo 9, in which four cameras were used simultaneously, each employing a different combination of film and filters: one used black and white film with a green filter; one had black and white film and a red filter; one used black and white film with an infrared filter; and one had color film with an infrared filter. Each of these different sensing devices gave a different representation of the scene photographed, emphasizing varying features.

We would encourage you in California to look into this program. NASA has 4 aircraft for use with this technique; also, there is a plan to employ it from future manned space stations. The Earth Resources Division is setting up this program now, and we feel that mosquito control should be on the ground floor in planning ahead to benefit from it.

CURRENT STATUS OF MOSQUITO CONTROL IN THE UPPER MIDWEST

A. W. Buzicky
Metropolitan Mosquito Control District
St. Paul, Minnesota

Officials responsible for mosquito control and mosquito control recommendations from North and South Dakota, Minnesota, Iowa, Wisconsin, Illinois, and Michigan were consulted recently relative to these subjects in their respective states. The following comments summarize the conclusions of these officials.

A. – Draining, Filling, Water Stabilization, Water Management

These permanent control techniques are used only sparingly in a few localities by control districts in Minnesota and Illinois. In the Twin City area, however, about 400 breeding sites are eliminated each year due to rapid urbanization of rural areas, and similar situations undoubtedly prevail in other metropolitan midwest communities. Creation of permanent deep water sumps by blasting or draglining normally dry depressions for wildlife habitat is becoming very popular and does restrict *Aedes vexans* production. Draining of potholes and tiling for agricultural purposes is still continuing and serves to reduce summer *Aedes* breeding in rural areas.

B. – Biological Control

Release of native fat-head minnows to selected sites is conducted on a limited scale in Minnesota and *Gambusia* similarly in the Chicago area. Martins, swallows and other insect eating birds are encouraged but no claim is made that they can effect mosquito control. Biological controls alone are ineffective for supressing mosquitoes in the midwest.

C. – Chemical Controls

1. Larviciding

Larviciding is systematically and effectively carried out only in the better organized control districts in Illinois, Michigan and Minnesota. When attempted by lay persons in small communities, the efforts are invariably failures because these people simply do not know what they are doing and always take in too small an area to prevent "blow-in". The most commonly recommended and used larvicides are Abate®, malathion, and No. 2 fuel oil with lesser quantities of fenthion, Dursban®, and Flit® MLO used. Applications are made to small sites with grass-seeders, knapsack sprayers, back pack power sprayers, mist blowers, and to large sites with fixed-wing aircraft and helicopters. Catch basin spraying is carried out only in the Chicago area.

2. Adulticiding

In the organized control districts in Illinois, Michigan, and Minnesota, adulticiding is secondary to larviciding and is carried on mainly when broods of *Aedes* mosquitoes are not in the water. The principal adulticides used are malathion, naled, and fenthion with methoxychlor, dichlorvos, Dursban, and carbaryl used to a much lesser extent. In all the states contacted, DDT has been withdrawn in 1970 for all mosquito control purposes; in most of these states it had already been withdrawn in 1969 or at least greatly restricted for both larviciding and adulticiding. Since practically all of the recommended toxicants are nonpersistent, fog applications are becoming more popular than mist blower or hydraulic sprayer applications.

Aerial adulticiding is still mainly done with dilute emulsion sprays. Some uninformed aerial sprayers with inadequate equipment have had some very unfortunate experiences with ULV applications with regard to car paint spotting and bird kills in urban areas. In Minnesota helicopter ULV adulticide applications of malathion and naled give generally unsatisfactory kills because of the screening out effect of overstory vegetation. Ground ULV applications to the shrub zone give excellent kills at half or less the aerial application rates.

D. – General

In Minnesota there is no evidence that *Aedes vexans* or *Culex pipiens* have developed any resistance to DDT, malathion, Abate or Dursban. In limited areas around Chicago *C. pipiens* has shown some resistance to DDT.

In the midwest, the degree of mosquito control obtainable with nonpersistent toxicants does not begin to approach that obtained in the past with DDT or other more persistent compounds. The lack of a prehatch material has severely hampered early season control efforts; the development of a safe, effective slow release granular formulation suitable for prehatch application would revolutionize mosquito control in the midwest. Currently used nonpersistent insecticides are not only more expensive than DDT but costs rise rapidly because of the necessity for making multiple applications. Funding sources have been very slow to provide additional money to meet these rising costs while environmental purists have insisted on elimination of the cheaper, more persistent toxicants.

BIOLOGICAL CONTROL OF MOSQUITOES – STATUS AND OUTLOOK

E. C. Bay
Division of Biological Control, University of California, Riverside

As of 1960 man had not yet entered space. Today we have twice visited the moon. On February 3, 1960, the AIBS (American Institute of Biological Sciences) convened a 2-day conference in Washington, D.C. with various military pest control agencies to discuss the biological control of insects of medical importance (AIBS 1960). Progress in this effort has been somewhat less dramatic. In 1960 we at least knew where the moon was with reference to the earth at any particular moment. This was more than we know today concerning the field relationship of mosquito populations to their natural enemies. At the end of the Washington conference, conclusions and recommendations that were made specifically in regard to mosquitoes included: (1) no known viruses, rickettsia, and perhaps bacteria appeared to offer any immediate potential for control of mosquitoes; (2) fungi, including *Beauvaria*, *Entomophthora* and especially *Coelomomyces* were considered to have the greatest immediate potential and *Coelomomyces* was recommended the highest priority; (3) only *Microsporidia* among the protozoa was known to cause high larval mortality. The most promising genera were considered to be *Nosema*, *Thelohania*, *Stempellia*, and *Plistophora*; (4) the mermithid nematodes were thought to have real promise and said to deserve investigation; (5) studies on the field effectiveness of larval and adult predators were recommended, especially quantitative field assessments of *Toxorhynchites* and larvivorous fishes in carefully selected sites to give valid and critical data.

Much good came of this meeting in inspiring new interest in the biological control of mosquitoes and the establishment of new programs. Our biological control projects at Riverside directed against public health insects were in part a product of this conference. Similar projects were later initiated at Berkeley. The World Health Organization's Environmental Biology unit in Geneva, Switzerland, under the former direction of Dr. Marshall Laird, a member of the Washington conference, greatly enhanced interest in natural enemies of mosquitoes through distribution of its mimeographed document series, and by sponsoring specialists as consultants to different countries. This work is now furthered by the WHO Vector Biology and Control Unit. In addition, in 1964, the WHO also established an International Reference Center for Diagnosis of Diseases of Vectors under the direction of Dr. John D. Briggs at Ohio State University. Other accomplishments include publication in 1964 of an annotated list and bibliography of pathogens, parasites, and predators of medically important arthropods by Dr. Dale W. Jenkins (1964), and a revision that first appeared as a WHO document in 1966 by Gerberich and Laird (1968) of J. B. Gerberich's 1946 annotated bibliography of papers relating to the control of mosquitoes by the use of fish. This contribution cited more than double the number of papers cited in the original work.

In recent years most research in the biological control of mosquitoes seems to have been directed at mosquito pathogens, perhaps because so relatively little is known about them. Among those literature references pertaining to natural control agents of mosquitoes cited in Mosquito News for the last 5 years including 1965, 56% or 89 out of 158 are devoted to microbes. Among the remaining papers, 26 concern predaceous insects and spiders, 15 refer to nematodes, 12 concern fish, and 6 cover subjects ranging from birds to manatees. Most of these papers are purely descriptive of host-parasite associations or individual predator capabilities studied in the laboratory. Most, especially those dealing with pathogens, are by the same few authors working either alone or with little support. Few papers concern findings that are of any immediate practical value.

Only larvivorous fishes so far can be used with any practicality as biological control agents of mosquitoes, and then only in those situations that are conducive to survival of the fish at prey regulating densities. Within the past 10 years increased attention has been given to the use of fish, especially the live bearers *Gambusia affinis* and *Poecilia reticulata*, for mosquito control. In Hawaii, as reported by Nakagawa and Ikeda (1969), principal reliance is on larvivorous fishes for the greater part of that State's mosquito control operation. The fish concerned are *G. affinis*, *P. reticulata*, *L. vittata*, and *Tilapia mossambica*. The first 3 species are live bearers and direct larvivores and the last, *T. mossambica*, is considered a biosynergist that by reducing weeds and algae makes larvae more available to other fish. Nakagawa and Ikeda find that fish seeded at a rate of 1,000 to 2,000 fish per acre usually multiply sufficiently within 6-8 weeks to give complete mosquito control.

In Iran, primarily on the recommendation of Mr. T.D. Mulhern, who was there in 1965 as a WHO consultant, widespread use is now being made of *G. affinis* in that country's malaria control program. The project is said by Tabibzadeh (unpublished report, WHO) to be showing excellent results in the reduction of exophilic *Anopheles* species.

In Bangkok, Sasa et al. (1965) reported widespread use of the guppy *P. reticulata* by the Insect and Mosquito Control Section of the Division of Public Health, Bangkok Municipality, for *C. fatigans* control in ground pools beneath low income housing. The value of these fish was observed by this writer during a WHO consultantship to Bangkok and Rangoon, Burma, in October, 1967. As a result of that consultantship, introductions of *P. reticulata* were made into *C. fatigans* breeding sites in Rangoon, although other populations of this fish were discovered already established there. These populations have now been monitored by WHO – Filiriasis Research Unit for 2 years. Larval control has been outstanding where fish populations already occurred, but it has been less distinguished where introduced populations have been having difficulty becoming established.

In California, where practical, *G. affinis* has been used by mosquito abatement districts for so long that it comes almost as a surprise to learn that these fish are just now being exploited in some western areas. A population was established at the Air Force Academy near Colorado Springs in 1966, and at Carson Air Force Base in 1968. At the town of Fountain, Colorado, near Colorado Springs, a mass rearing effort is under way in artificially heated ponds to produce large populations of *G. affinis* during the winter for early spring distribution (Pest Control 1969). In New Mexico at Las Cruces when in 1967 *Aedes* populations in drainage ditches and flood seepage areas began to develop high O.P. resistance, the Donna Ana County Health Department turned to *G. affinis* and other top minnows. The project has been so successful that the county has developed a small biological control laboratory for additional fish studies and has received $20,000 state support for its 1969-70 operation (Miller personal communication).

For many years insecticides have been a magnificent tool for mosquito control. Today, however, aside from the concern for environmental pollution, the problem of broad-scale, insecticide-resistant mosquito strains is a serious one not only for California's Central Valley, but also for the World Health Organization's many programs. As a consequence, informal discussions were held last December in Geneva to consider alternative approaches for vector control, primarily mosquitoes. The discussions lasted for one week and involved specialists from the United States, Canada, Great Britain, and Africa. Some of the participants had also been members of the AIBS conference in Washington in 1960. After broadly discussing the problems of mosquito control in general, the group discussed critically the relative merits and disadvantages of what are today thought to be the more promising natural agents and alternative methods for mosquito control. As compared with the recommendations of the AIBS conference in 1960, recommendations of the WHO group include the following: (1) develop culture methods for the *Aedes*-lethal bacillus BA-068 discovered by Dr. E.L. Reeves of the Division of Biological Control at Riverside; (2) develop methods of producing *Coelomomyces* and obtaining infections with it; (3) develop culture methods for *Romanomermis* nematodes for distribution as eggs; (4) develop production methods for *Toxorhynchites brevipalpis* or other *Toxorhynchites* for proper pilot trials; (5) develop well ordered pilot field trials with live bearing fishes and annual fishes in selected habitats. It will be observed that these recommendations parallel very closely those of the AIBS conference in 1960 except that a bacillus is now seriously considered and microsporidia are left out. The bacillus unlike most pathogens is readily infective, can be mass produced on artificial culture media, and has already shown promise in very small field trials. Other areas of investigation that the group considered worthy of support include further studies of algal extracts, such as described in the work of Amonkar and Reeves that was reported here this morning, and studies of mosquito larva crowding pheromones by Ikeshoji, that are to be reported later at the conference. I personally consider these last two projects, the algal substances and the crowding pheromones, to be especially worthy of support. Both of these substances are chemicals natural to the aquatic environment at some time or other and as such can hardly be considered pollutants in the conventional sense. Moreover, these are chemical compounds that should be subject to synthesis whereupon they hold the promise of storage, dispersibility and range of application common to other insecticides. The one thing needed for all of these projects is adequate and determined support.

The moon landings in 1969 were the accomplishment of a superbly organized effort that employed thousands of dedicated specialists funded by tens of billions of dollars. The year 1969 culminated an illustrious decade for physics, chemistry, and engineering. The decade of the 70's that we are now entering is shaping up strongly to be as dedicated to ecology and to saving the quality of our environment. To what extent this will affect us in mosquito control remains to be seen. It is hoped, however, that this atmosphere of concern will promote more deeds than words in assessing how, when, and where the biological control of mosquitoes, as well as of other insect pests can be accomplished.

References Cited

A.I.B.S. 1960. Biological control of insects of medical importance. Technical report (The American Institute of Biological Sciences) November 1960. Technical Editor, D.W. Jenkins.

Gerberich, J.B. and M. Laird. 1968. Bibliography of papers relating to the control of mosquitoes by the use of fish, an annotated bibliography for the years 1901-1966. FAO Fisheries Technical Paper No. 75:1-70. [Also appeared unpublished as WHO mimeographed document WHO/EBL/66.71, WHO/Mal/66.562.]

Jenkins, Dale W. 1964. Pathogens, parasites and predators of medically important arthropods, annotated list and bibliography. Supplement to Vol. 30, Bull. World Health Organization: 1-150.

Nakagawa, P.Y. and J. Ikeda. 1969. Biological control of mosquitoes with larvivorous fishes in Hawaii. WHO/VBC/69.173. [Unpublished, distributed as mimeographed document.]

Pest Control. 1969. *Gambusia* for Colorado. Pest Control 37(4): 28-38.

Sasa, M., T. Kurihara, O. Dhamvanij and C. Harinasuta. 1965. Studies on mosquitoes and their natural enemies in Bangkok, Part 3. Observations on mosquito-eating fish "guppy", *Lebistes reticulatus*, breeding in polluted waters. Japanese Jour. Exptl. Med. 35(1):23-80.

SYSTEMATICS OF MOSQUITOES

Richard M. Bohart
Department of Entomology, University of California, Davis

Systematics deals with more than 1 million species of animals, the majority of which are insects. The order Diptera to which mosquitoes belong is one of the 4 largest in the class Insecta. The family Culicidae contains about 2500 described species and therefore rates as a moderately large family.

In general the term "systematics" includes everything relating to species and their place in the scheme of things. Therefore, evolution, biology, ecology, and geographical distribution are all part of the subject. Important subdivisions are classification (family, genus, species, etc.) and nomenclature (naming of the various categories).

The importance of correct identification is widely recognized. In fact, taxonomy is the cornerstone of science. The first question asked by a child or by a scientist is, "What is it?" When that is answered correctly, facts can be accumulated about it and worthwhile communication of assembled information is possible. There are many examples of confusion resulting from incorrect identifications. It is now known that mosquito larvae may differ in their reactions to insecticides by as much as 35 times. This accounted for many early and puzzling failures in treatments of ponds which contained larvae of several species. One interesting situation outside the realm of mosquitoes is the recent discovery of a corn earworm, *Heliothis stombleri*, the moth of which is externally indistinguishable from the well known universal pest *Heliothis zeae*. At least 2 other species are difficult to distinguish from the corn earworm as adult moths. In economic studies utilizing light traps to determine seasonal abundance and flight range, scientific results demand accurate determination of the moths.

This brings up another problem of special concern to economic entomologists, including mosquito abatement personnel. Why are name changes necessary? Situations as described above, with discovery of species complexes are one answer. In other words, "the corn earworm" of 50 years ago is now known to be 3 or 4 species. We have seen this happen also in mosquitoes where "*Culex apicalis*" is now known to involve 4 species in California. Similarly, "*Aedes varipalpus*" has been shown to be a complex containing *Aedes sierrensis*, and the true *varipalpus* does not even occur in California.

Another source of change is the discovery of names antedating those in use. The International Rules of Zoological Nomenclature give priority to the first described. Thus, we have seen *Culex stigmatosoma* give way to *Culex peus*, and *Culiseta maccrackenae* change to *Culiseta particeps*. Where important agricultural or medical involvements occur, the International Commission may, upon request, place threatened names on an official list of "Nomina Conservanda".

According to the well known synoptic catalog of mosquitoes by Alan Stone and others, published in 1959, some 450 authors have contributed significantly to mosquito systematics. Their studies can be grouped into 3 major periods: before World War II, during World War II, and after World War II. Unquestionably, this conflict was responsible for a great resurgence of effort in mosquito systematics, as large numbers of entomologists concentrated on insects of medical importance.

Publishing has been done in a great variety of journals, especially those dealing with public health or parasitology, but even more general ones such as "Proceedings of the Entomological Society of Washington" and "Annals of the Entomological Society of America" have been frequent recipients of papers. "Mosquito News" has taken some part but its special value to systematists is the "taxonomy" section under current literature. An interesting new development started by Kenneth L. Knight at North Carolina State University is the "Mosquito Systematics Newsletter" devoted solely to systematics. It is now starting its second year.

A quick look at mosquito species shows that the approximately 2500 species are arranged in 110 genera and subgenera. Of these, *Aedes* has 23 subgenera, *Culex* has 16 subgenera, and *Anopheles* has 6 subgenera. In many other insects, subgenera of the size and distinctness of those in *Aedes* have long since been raised to the generic level. This has practical value but some drawbacks. In any case, tradition and sentimentality have held back the elevation of divisions in *Aedes* and other large mosquito genera.

An interesting fact to contemplate is that there are generally fewer species of mosquitoes as one moves from the equator to the poles. Thus, Brazil has about 365 described species, the Philippines 240, California about 50, the so-called "frozen north" as few as 4, and the Arctic Circle fauna only 1. Total numbers of specimens do not follow this progression, however. The explanation of the large numbers of species in tropical areas lies in the correspondingly great number of ecological niches available.

Much has been promised to mosquito systematics by "new approaches". Chromosome studies, serology and paper chromatography have all made contributions for which we are grateful. Yet, because of the time required for such detailed studies, these and other new methods have so far just scratched the surface. Another approach is numerical taxonomy. This does not contribute truly new information but seeks to clarify systematics by an objective and computerized look at problems. This, also, is quite time consuming. So far, the numericists have been largely concerned with developing methodology. Hopefully, they will make real contributions in the future.

ECOLOGICAL STUDIES OF MOSQUITOES ASSOCIATED WITH CALIFORNIA RICE FIELDS: A PROGRESS REPORT

R. K. Washino, P. A. Gieke and W. Ahmed
Department of Entomology, University of California, Davis

The purpose of this report is to summarize briefly the status of studies on the ecology of mosquitoes associated with California rice fields. The studies are concerned with two areas: (1) to study the ecology of the larvae of *Culex tarsalis* and *Anopheles freeborni* in the rice field environment; (2) to study *Anopheles freeborni* in the adult stage, with emphasis on the fall-winter-spring periods in areas away from, as well as near, the rice field environment. The ultimate objective is to seek the most effective means of controlling the two mosquitoes associated with rice cultivation in California.

Ecological Studies in the Rice Field Environment

A comparison was made between an aquatic light trap having four lateral entrances with the conventional trap (Husbands 1967) which has a single vertical entrance. Both types of traps were operated one night a week for eight consecutive weeks. The advantages of the modified trap were thought to be the greater accessibility primarily to organisms found on the surface (i.e., anophelines), and greater ease for operating in rice fields where shallow water culture is practiced. No obvious qualitative or quantitative advantages were observed in the modified trap. It attracted Crustaceans as well as the unmodified ones, but slightly less of some of the aquatic insects. The trap did not collect *A. freeborni* or any more neuston animals than did the unmodified trap.

Studies on insect predators of mosquitoes in rice fields in the Sacramento Valley were continued. In particular, the giant water beetle (*Hydrophilus triangularis*) was studied intensively this year to learn its seasonal cycle and feeding pattern. The feeding pattern of this beetle was studied by examining the digestive tract of 786 larvae collected from rice fields in 1966 and 1969. In some instances, *C. tarsalis* larvae were found in the digestive tract of the beetle larva, but chironomid midges and seed shrimps (Ostracoda) appeared to be the main food item for these immature beetles. The evidence so far indicates that these beetles will feed on food animals that are most abundant and available. The beetle larvae were present in the rice fields for 12 weeks in 1966 and for eight weeks in 1969, but they never became as abundant as other members of the family Hydrophilidae (i.e., *Tropisternus lateralis*). Feeding by adults appears to be limited to plant matters. The opportunistic feeding pattern, the relatively limited abundance and seasonal distribution of *H. triangularis* in rice fields indicate that this species is not a primary factor in controlling mosquitoes in rice fields. Details of this study are discussed in another report (Veneski and Washino 1970).

Laboratory studies have been initiated to determine the tolerance levels of insect predators to pesticides currently used for mosquito control purposes in California rice fields. Early results indicate considerable variability in tolerance levels exhibited by different species of predaceous beetles. The tolerance levels for the four species of beetles presently being studied are all higher than levels for both *A. freeborni* and *C. tarsalis.*

Rice fields in the Sacramento Valley of California are being studied to determine why *Gambusia affinis* becomes established with ease in some rice fields and only with difficulty in others. The speculation that water quality (i.e., excessive boron) is the limiting factor in rice fields in certain areas is being investigated. Analysis of the irrigation water for boron, nitrate and ammonia nitrogen, total phosphate, etc., so far does not indicate that chemical factors are a limiting one.

The feeding pattern of *G. affinis* was studied from fields where mosquito control was, and was not, being achieved to determine why these fish reduce the mosquito population to a greater extent in one field more than in others. Preliminary results are discussed elsewhere (Ahmed et al. 1970).

Earlier California studies have shown that some mortality is encountered by *G. affinis* with materials such as parathion (Lewallen 1959; Mulla 1961). To minimize such mortality, the feasibility of utilizing an organophosphate resistant stock of *G. affinis* (Ferguson et al. 1966) is being considered. Local strains of the mosquito fish are being tested to determine tolerance levels against at least four organophosphorous compounds. Preliminary results indicate that strains of fish so far tested show some tolerance to parathion and considerable tolerance to methyl parathion. These tests are discussed further elsewhere (Ahmed et al. 1970).

Studies on Overwintering *Anopheles freeborni*

Studies on the effects of decreasing photoperiod on physiological changes in the overwintering *A. freeborni* females were continued. Females reared under short-day condition exhibited diminished biting activity and were more apt to undergo reproductive diapause than females reared under long-day conditions.

Since some blood feeders are found with the non-blood feeders in the fall-winter field population, a comparison was made of the lipid content and survival rates in the two groups. Blood-engorged females which developed mature eggs died mostly within the first 30 days and considerably earlier than females feeding on sugar- or blood-engorged females which were in a reproductive diapause. No differences appeared to exist between the latter two groups. Small but rather consistent differences were observed in lipid content of blood- and sugar-fed females reared under short-day conditions. There was insufficient evidence to support the possibility that a blood meal is clearly advantageous or disadvantageous to the overwintering female. In studies on the overwintering field population of *A. freeborni*, no difference in parity was observed between blood- and non-blood-feeders (McKenna and Washino 1970).

References Cited

Ahmed, W., R.K. Washino and P.A. Gieke. 1970. Further studies on *Gambusia affinis* (Baird and Girard) in California. Proc. Calif. Mosq. Control Assoc. 38:

Ferguson, D.E., D.T. Gardner and A.L. Lindley. 1966. Toxicity of Dursban to three species of fish. Mosq. News 26:80-82.

Husbands, R.C. 1967. A subsurface light trap for sampling aquatic insect populations. Vector Views 14:81-82.

Lewallen, L.L. 1959. Toxicity of several organophosphorous insecticides to *Gambusia affinis* (Baird and Girard) in laboratory tests. Mosq. News 19:1-2.

McKenna, R.J., and R.K. Washino. 1970. Parity of fall-winter populations of *Anopheles freeborni* in the Sacramento Valley, California: a preliminary report. Proc. Calif. Mosq. Control Assoc. 38: 92-93.

Mulla, M.S. 1961. Field studies on the toxicity of insecticides to mosquito fish *Gambusia affinis*. J. Econ. Entomol. 54:1237-1242.

Veneski, R., and R.K. Washino. 1970. Ecological studies of *Hydrophilus triangularis* Say in the laboratory and in a rice field habitat: a preliminary report. Proc. Calif. Mosq. Control Assoc. 38: 94-95.

PROGRESS REPORT ON THE MOSQUITO CONTROL RESEARCH AND OPERATIONAL GUIDE PROJECT BY PERSONNEL OF THE AGRICULTURAL ENGINEERING DEPARTMENT, UNIVERSITY OF CALIFORNIA, DAVIS

Norman B. Akesson

Agricultural Engineering Department, University of California, Davis

Funds were received in the summer of 1969 from several mosquito abatement districts in the Sacramento Valley to aid the Agricultural Engineering Department personnel in developing operational procedures for aircraft use in mosquito control, particularly as it relates to the large acreage problems in northern California. Plans were developed to first establish certain limitations of aircraft flight height, weather conditions, swath widths, dosage rates and atomizing equipment which could form the base for recommendations and be developed into an operational guide or use manual. The field research and laboratory program was designed to obtain sufficient field test information so that as a computer model was developed, we could make positive checks against the model by these tests.

During 1968 a series of tests were run in the Colusa area (one set in Bakersfield) which opened to question the problem of controlling deposit of sprays released from heights up to 2000 ft. The data obtained from these indicated the feasibility of such runs for broadly spreading materials and many observers were convinced that the control of the spray deposit could be achieved without too great a difficulty.

However, plots of the Pibal (pilot ballon) tracking done during the 1968 tests indicated the serious variability that was to be found in: (a) wind velocity gradient from ground surface to 2000 feet (as much as 20 mph difference, 10 ft to 2000 ft), (b) considerable variation and dependence on the temperature gradient (stable vs. turbulent air) and the implications of downwind air transport involved with this (see data, Table I), and (c) the variability of wind direction from surface to 2000 ft elevation where as much as a 90 degree wind shift has been seen.

These tests in 1968, and from similar weather data we have accumulated over a considerable number of years of field tests, made us feel that spray releases above 500 ft were basically unpredicatble, even under stable atmospheric conditions, and should not be used on an operational basis. Thus, we felt that a more orderly examination should be made by conducting field studies on this drift type of aircraft application and collecting data on as many of the variables involved in this operation as possible, while holding others as near constant as it is likely to be possible in field testing. The obvious gains in swath width and acreage covered make this especially attractive, but more predictability certainly was needed.

Step One, Field Tests

During 1969 a series of 6 test runs were made (some replicated) with 2 standard flat fan type nozzles (one at 60 and one at 80 psi) and one with a very fine spray, twin fluid, or air atomizing type. Only two application heights were run, one at 5 to 10 feet and the other at 25 to 30 feet. A low volatility glycerol with soluable fluorescent dye tracer was used as a spray material and discharge rates were at 1 to 2 gpm or equivalent to a few ounces per acre depending on what swath width was chosen. The aircraft was a Piper Pawnee 150 equipped with an electric pump drive system, and special air tanks and air atomizers (twin fluid) were used for the fine spray runs. Weather was usually stable, under evening inversion conditions, with low winds of 3 to 5 mph.

We tried to produce sprays of the order of 150 to 250 microns VMD (vol median dia) with the fan nozzles aimed down, or perpendicular to the air stream, and operated at 60 to 80 psi. We hoped that the fine spray system would give us 50 to 75 microns VMD. Further laboratory testing on accurate drop sizing will be needed to determine what size range we actually produced as the viscous glycerol was not easily atomized. The weather conditions at the time of spray applications, the atomization or fineness of the spray, plus the non-evaporative formulation of the spray would be the controlling factors affecting the deposit distribution on these tests. Even from the height of 5 to 10 feet the downwind fallout of the spray with the coarsest nozzle (80015) indicates (see Table 1) 1200 ug/ft^2 at 50 ft, 100 ug at 200 ft and 5 ug at 1000 ft. The next finer spray (M-20 at 80 psi) indicates 1400 ug/ft^2 at 50 ft, 180 ug at 200 ft and 10 ug at 1000 ft, while the finest spray (2850 twin fluid) at 25 ft altitude and under temperature inversion conditions shows 2100 ug/ft^2 at 50 ft, 240 ug at 200 and 26 ug at 1000 ft.

The strong effect of the weather conditions can be seen in the 2850 nozzle at 5 ft and 0.8 S.R. (stability ratio). The higher S.R. the greater the temperature inversion, while S.R. less than 1.0 indicates turbulent or mixing air. Thus, this run under turbulent or mixing weather shows low levels of 400 ug at 50 ft and only 50 ug at 200 ft, but holding up to 5 ug at 1000 ft and getting higher than the coarsest spray at 5000 ft with 0.7 ug having 0.3 ug even at 10,000 ft downwind.

The data on Table 2 corresponds to runs of Table 1 by showing the air burden or air-carried amounts at several downwind points to 5 miles for the same run as Table 1. Now the finest spray and highest height has also the greatest air transport with 10.5 ug at ½ mile and still 3 ug at 5 miles. The 5 ft height (2850 nozzle) run with turbulent weather shows about ½ the airborne levels of the inversion run with the same atomization. The two fan nozzle runs at 60 psi and 80 psi show airborne material at levels in keeping with fineness of the spray with the 80 psi about 2 times higher than the 60 psi run at all points. It is evident that "inversion" weather is desirable for drift type, wide swath runs.

Because we are getting sharp drop in the fallout residue of 3 to 4 times between the 50 and 100 ft stations, even at 25 ft altitude, it would appear that a finer spray and higher altitude should be tried in the tests this 1970 season. The rate of dye application works out to be about 0.1 lb/acre for the 1000 ug/ft^2 collection, thus at 250 ug/ft^2 there would be about 0.025 lbs/acre. Examining the data of Table 1 we can see that the fine spray at 25 ft altitude, gave us a 200 ft swath at 0.025 lbs/acre but the drop off of this from 0.2 lbs/acre at the 50 ft level does not give very good swath distribution. It is evident that further tests of this type which includes air-carried material information need to be run. Unfortunately, our in-swath data taken with one gallon cans was lost due to reaction of the glycerol with the tin of the can.

We plan to continue these tests and also participate in a series of field mosquito trials to be run in the Colusa Mosquito Abatement District in 1970.

Table 1. Downwind tracer deposit on Mylar® sheets 108 in^2 per pass of aircraft flown on a single course.

Downwind ft				50	100	200	500	700	1000	2000	5000	10,000
Noz.	alt ft	S.R.***	psi									
2850*	25	5.5	60	2100	700	240	70	43	26	10	2.2	1.0
M-20**	5	9.3	80	1400	500	180	40	20	10	3	.5	.12
80015	5	8.8	60	1200	320	100	20	10	5	1.1	.2	.04
2850*	5	0.8	60	400	120	50	12	9	5	2	.7	.3

Table 2. Air burden collected on glass fiber filters per pass of aircraft flown on a single course. Total ug/ 4 in. dia. filter. Flow rate 20 cubic feet per minute.

Downwind miles				1/2	1	2	3	5
Noz.	alt ft	S.R.***	psi					
2850*	25	5.5	60	10.5	5	3	3	3
2850	5	0.8	60	3.1	2	1.6	1.5	1.5
M-20**	5	9.3	80	2	.85	.4	.3	.2
80015*	5	8.8	60	.9	.32	.2	.18	.17

* 2850 are twin fluid (air and liquid) nozzles and used 60 psi on both air and liquid.

** M-20 is similar to an 8002.

*** Stability ratio.

Step Two, Operational Analysis

The operational guide has started with the simple relations of aircraft and nozzle discharge, or calibration techniques and has progressed through to information relating to operational efficiency for different aircraft loads, swath widths, rate of application, ferry distance and air speed. The data of the aircraft operations will be put together with the data on swath width, spray atomization and weather, and we expect to generate computer studies relating these functions to the overall use of aircraft in mosquito control work as the next step in our overall project.

We will plan to have the first part of the guide manual as separate sheets as soon as possible. We will be continuing our work on the computer program for prediction of swath width, and also total spray budget or percent recovery, so that a measure not only of deposited spray can be made, but also a measure of losses to the atmosphere and the general environment can be obtained.

MEASURING SUSCEPTIBILITY OF *ANOPHELES FREEBORNI* AITKEN TO ORGANOPHOSPHORUS LARVICIDES

Don J. Womeldorf[1] and Robert K. Washino[2]

Introduction

The California mosquito larvicide susceptibility surveillance program, conducted cooperatively by local mosquito control agencies and the California Department of Public Health, monitors developing resistance in important mosquitoes. *Anopheles freeborni*, one of the major species, has received insufficient attention in the past because of the difficulty in collecting late-instar larvae in adequate numbers to permit comprehensive testing. Attempts to rear the more easily caught early instar larvae, using procedures successfully employed with *Culex* spp. or *Aedes* spp. were not satisfactory because the larvae died or were obviously weakened.

One of the research programs conducted by the University of California is aimed at elucidating the ecology of ricefield mosquitoes. Since part of the major effort in this program involved rearing *A. freeborni* in large numbers in the laboratory, the aid of these workers was enlisted to overcome the difficulty of obtaining adequate numbers of late-instar larvae to permit comprehensive testing of insecticide susceptibility.

This paper describes procedures used to collect, rear, and test *A. freeborni* larvae as applied during 1969, and draws upon their responses to parathion for some examples. Complete testing results to date will be published elsewhere.

Materials and Methods

Studies in the University of California ricefield mosquito ecology project involve various tests on progeny of field collected adults. Larvae which could be spared from tests were utilized for susceptibility determination. Adult females were periodically collected from an area near Meridian, Sutter County, adjacent to two mosquito abatement districts. Over 500 mosquitoes per collection were caught with a mechanical aspirator as described by Bailey (1966).

Blood engorged and gravid females were isolated in large glass test tubes partially filled with water and sealed with cotton plugs. Females were held until eggs were deposited in the water. Field-collected females which contained neither blood nor eggs were placed in a cage made from a three gallon cardboard container, the top of which was covered with nylon mesh. White mice were used for blood feeding, and as a supplementary food source, pads soaked in 20% sucrose solution were also provided. A small dish of tap water was left in the cage for oviposition.

Eggs oviposited in the glass tubes or dishes were transferred to enamel pans containing tap water. Until the eggs hatched a glass cover was placed over the pan to minimize evaporation and the water was kept very shallow. After hatching, 50 to 75 larvae were transferred to an uncovered enamel pan. The larvae were reared without aeration and fed pulverized Gaines non-fat dog food. The dog food was obtained directly from the manufacturer prior to the fat being added as in the commercial preparation. The rearing room was maintained at 78–80°F and lighted for 16 hours per day.

To have sufficient numbers of fourth instar larvae available for testing at one time, it was sometimes necessary to restrain pupation by holding the early fourth instars in a 55°F cabinet.

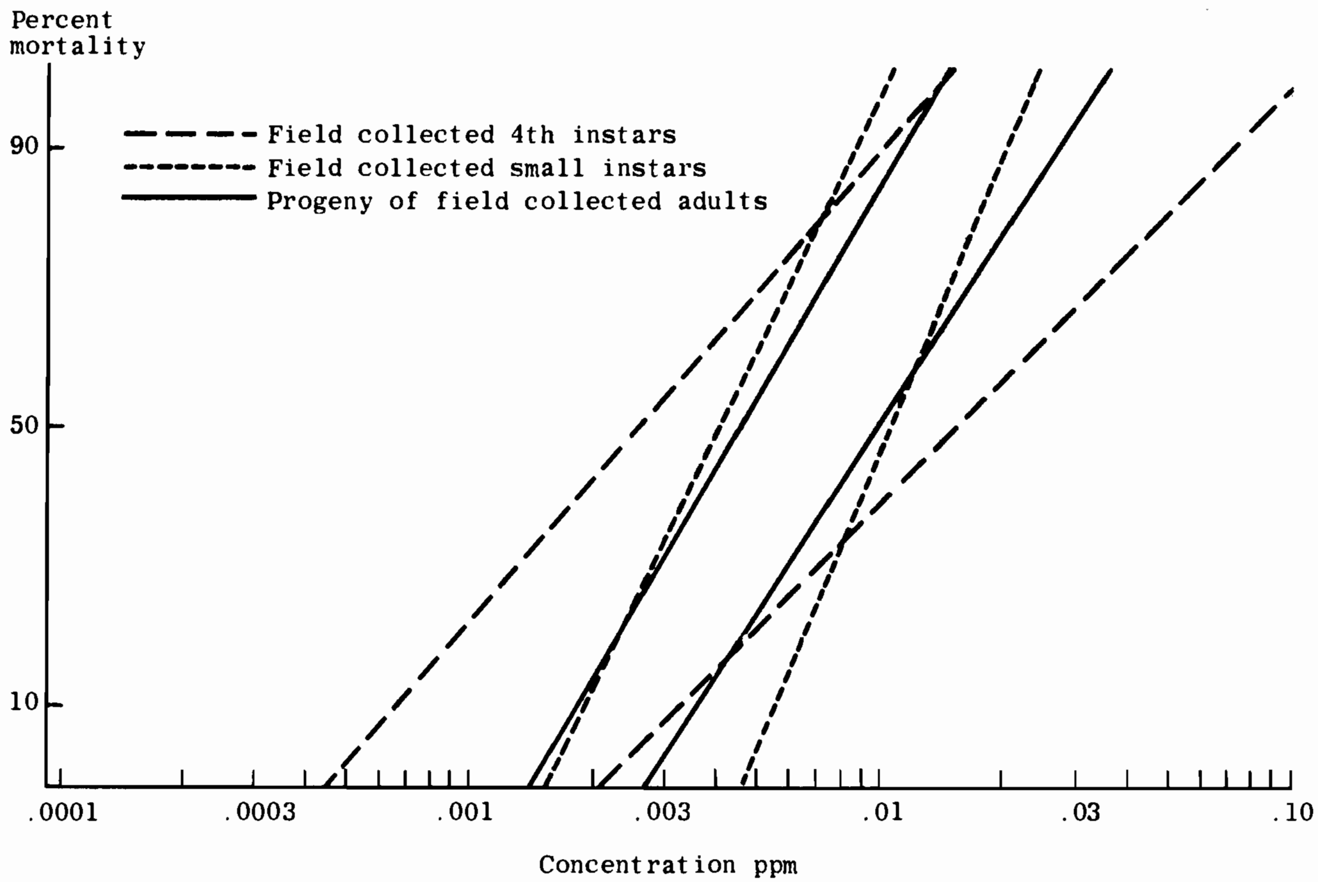
Field collections of larvae for testing were made as described by Gillies and Womeldorf (1968). *A. freeborni* are notoriously sparsely distributed under field conditions and so a great many dips were necessary to obtain an adequate number. A nylon mesh bag larval concentrator was used, with debris being removed frequently since the larvae were found to be quite susceptible to damage when crowded by accumulated floating material. They were most safely transported to the laboratory in one-half to one inch deep water in an icechest (without ice) as quickly as was feasible. Larvae were obtained from Butte, Sutter, Yuba, and Placer Counties, all in the central and lower Sacramento Valley. The sources were within and adjacent to mosquito control districts.

In the laboratory, they were hand-sorted by using an eyedropper pipette. Fourth instar larvae were tested immediately while smaller larvae were reared as described above. Larval test procedures were as described by Gillies and Womeldorf (*ibid.*). A conservative criterion of mortality was used since the larvae responded rather erratically when touched with a probe. Only larvae that had very definite inability to move normally when probed were counted as moribund.

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

[2]Department of Entomology, University of California, Davis.

Figure 1. Parathion responses of 4th instar Anopheles freeborni.



Results and Discussion

Figure 1 shows the range of log concentration-probit lines determined against parathion on larvae obtained as field-collected fourth instar, on field-collected small larvae (first through third instars) reared to the fourth stage, and as fourth instar progeny of field collected adults.

Within each group, the slopes of the lines (which reflect variances within the test populations) did not differ significantly. The differences between slopes of the three groups were statistically significant. There was greater variance of response among the field-collected fourth instar larvae than among those in the fourth stage reared from field-collected small larvae, as shown by the flatter slopes. The variance of response of progeny of field-collected adults was intermediate.

The greatest range of mean lethal concentration (LC_{50}) levels occurred in tests of field-collected fourth instars. In addition, this range bracketed the LC_{50} ranges for the other two groups.

The results of these determinations demonstrate that laboratory-reared larvae, obtained as early instar larvae or as the progeny of field-collected adults, tend to show parathion LC_{50} levels similar to field-collected fourth instar larvae. However, the slopes of their response lines can be expected to be steeper.

It appears that tests of *A. freeborni* fourth instar larvae, reared in the laboratory either from field-collected small instar larvae or as progeny of field-collected adults, can be utilized in the mosquito susceptibility surveillance program. The information obtained can be compared with data developed by testing field-collected fourth instar larvae.

Acknowledgments

Personnel of several mosquito control agencies aided in collecting larvae from the field. Paul A. Gieke, Department of Entomology, University of California at Davis, reared all larvae. Dr. K.E. White, Bureau of Vector Control and Solid Waste Management, California Department of Public Health, advised on statistical aspects of this report.

References Cited

Bailey, S.F. 1966. A suction-type collecting apparatus for mosquitoes. Mosquito News 26(4):585.

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.

ASSOCIATION OF INSECTICIDE STRUCTURE AND RESISTANCE IN *AEDES NIGROMACULIS*

Charles H. Schaefer and William H. Wilder
University of California, Fresno

Insecticide resistance in *Aedes nigromaculis* is a problem on which the Fresno Laboratory has devoted major studies for several years. In the process of evaluating dozens of candidate insecticides, we have found a general relationship between the degree of resistance and type of compound.

A. Chlorinated Hydrocarbons. Since chlorinated hydrocarbons haven't been used for controlling *A. nigromaculis* for many years, the question is frequently raised as to whether or not the field populations have lost their resistance to this class of compounds. The present organophosphorus-resistant strains are also resistant to chlorinated hydrocarbons. While most chlorinated hydrocarbons could not be used now, because of residue problems, there is one compound, methoxychlor, which does degrade. Unfortunately, resistance to methoxychlor is also high (Table 1).

B. Organophosphorus Compounds. The organophosphorus-resistant strains show some tolerance to every new organophosphorus compound which we have tested. There is considerable cross resistance to compounds which have a close structural similarity to parathion, e.g., Sumithion®. Significant organophosphorus resistance occurs in the adult as well as in the larval stage (Table 2).

C. Carbamates. Both larvae and adults of the organophosphorus resistant strains show only low degrees of tolerance to carbamates (Tables 1 and 2). Thus, carbamates appear to offer promise as control agents, but we can also expect carbamate resistance after several years of field use.

Relationship Between Laboratory Resistance Levels and Field Performance

From past experience we had known that, when a resistant population of *A. nigromaculis* showed over 5 times tolerance (LC_{50} R-strain/LC_{50} S-strain) in laboratory tests, operational failures would be expected. But what does a 3- to 4-fold tolerance in laboratory tests signify? To evaluate this question we selected Bay 77488 and Akton®, which both showed 3-fold larval tolerance, and Cidial®, which showed a 7-fold tolerance (Table 1), for comparative

Table 1. Insecticide resistance levels for *Aedes nigromaculis* larvae.

Insecticide	Susceptible strain LC_{50} (ppm)	Resistant strain LC_{50} (ppm)	Resistance ratio*
methoxychlor	.057	1.15	20
parathion	.0035	.23	66
Sumithion®	.0020	.15	75
fenthion	.0013	.012	9
Dursban®	.00070	.0048	7
EPN	.0011	.0053	5
Akton®**	.0099	.026	3
Cidial®**	.0035	.024	7
bromophos	.0099	.12	12
Bay 77488**	.0024	.0062	3
Ciba 9491	.0037	.043	12
Furadan®	.093	.12	1.3
RE11775	.0042	.009	2

* LC_{50} R-strain/LC_{50} S-strain

** Failed at 0.1 lb/acre against R-strain

Table 2. Insecticide resistance levels for *Aedes nigromaculis* adults.

Insecticide	Susceptible strain LC_{50}*	Resistant strain LC_{50}*	Resistance ratio**
parathion	.017	7.8	460
fenthion	.0068	.15	22
Dursban®	.0031	.015	5
Dibrom®	.0054	.062	11
Baygon®	.011	.017	1.6
Furadan®	.020	.028	1.4
RE11775	.0093	.015	1.6

* % solution applied to filter paper

** LC_{50} R-strain/LC_{50} S-Strain

field evaluations. All applications were 0.1 lb per one-half gallon of water per acre applied by aircraft. Bay 77488 gave excellent results against a susceptible strain (East Side MAD); however, a similar test against an organophosphorus resistant strain (Tulare MAD) resulted in 80-90% control, even though application conditions were good. Akton, in two separate field tests involving 15 acres each, gave only 70-80% mortality of organophosphorus-resistant larvae and Cidial gave only about 40% mortality (Tulare MAD). Thus, for organophosphorus compounds, resistance levels of 3- to 4-fold in laboratory tests are significant with respect to the more resistant field populations of *A. nigromaculis.*

CONSIDERATIONS ON THE RELATIONSHIP OF LARVAL AND ADULT TOLERANCE TO INSECTICIDES IN MOSQUITOES[1]

G. P. Georghiou
Department of Entomology, University of California, Riverside

It is an established fact that an insecticide, used effectively against one stage of an insect, such as the larvae, would not necessarily be useful against adults, and vice versa. This phenomenon has been well known since the days of the arsenicals but it tended to be overlooked during the period of use of the wide-spectrum chlorinated hydrocarbon insecticides DDT, lindane and dieldrin. However, that fact again became apparent with the advent of the organophosphates and carbamates.

In Table 1, 10 common insecticides are ranked in order of decreasing toxicity to *Anopheles albimanus* larvae and adults. Some of these insecticides are rated as highly toxic to both larvae and adults; for instance, Dursban® is the most toxic of these compounds to both stages of the mosquito. Also, DDT, fenthion, bromophos and malathion are all about as toxic to larvae as to adults. In contrast, Abate® is a very effective larvicide but an ineffective adulticide. At the other extreme, promecarb and propoxur (Baygon®) are relatively weak larvicides but good adulticides.

Since organophosphates and carbamates affect the insect's nervous system mainly by inhibiting cholinesterase, and since the enzyme is present in both larvae and adults, one might expect that each material would exhibit the same relative toxicity to both stages of the insect. This is indeed the case when the extent of enzyme inhibition is measured *in vitro*, in tissue homogenates. But in the living insect the situation may be quite different, primarily because the *in vivo* toxicity of a given insecticide is greatly influenced by the rate at which the chemical reaches the site of action within the insect. Therefore, factors such as the chemical stability of the compound in water, air, sunlight, on plants or other surfaces, its rate of penetration through the integument of the insect, and its activation and metabolism within the insect, all influence the amount of toxic chemical that reaches the site of action. Thus, since mosquito larvae and adults live in distinctly different environments, it is not surprising that the performance of an insecticide might differ in these two situations.

That the observed toxic effect is the net result of several

[1]Part of the research reported here was supported by Public Health Service research grant CC 00301 from the National Communicable Disease Center, Atlanta, Georgia.

interacting rates, such as hydrolysis, penetration, metabolism, etc., is illustrated in the following examples. These are taken from our work, only, since it is not my intention, at this time, to review the extensive literature on the subject.

Studies on the extent of knockdown of larvae of *Culex quinquefasciatus* exposed to propoxur (Figure 1 – top) indicate that a plateau is reached within 8 to 12 hours. At this point, the rate of accumulation of the insecticide within the insect must be equal to or just below the rate of its metabolism by the insect. This point is reached more slowly with some insecticides than with others, as shown by the results obtained with carbofuran (Furadan®) (Figure 1 – bottom). If the larvae are transferred to clean water after a brief exposure to propoxur, some of them recover because the penetration is now well below the rate of metabolism (Figure 2). This is more obvious in the resistant strain, which contains a greater supply of propoxur-metabolizing enzymes.

A similar trend has been observed in adult mosquitoes. Removal of the insect after a brief exposure to the residue of carbamate insecticide results in partial recovery from

Table 1. Ranking of various insecticides in order of decreasing toxicity to larvae (left) and adults (right) of *Anopheles albimanus* Wied.

Larval LC_{50} (ppm)		Adult LC_{50} (log scale) / Larval LC_{50} (log scale)	Adult LC_{50} (ug/cm^2)	
0.006	Dursban		Dursban	0.18
			DDT	0.23
0.011	Abate			
0.012	Fenitrothion			
0.015	DDT			
0.016	Fenthion			
			Promecarb	0.55
			Propoxur	0.82
0.034	Bromophos		Bromophos	0.95
			Fenthion	1.20
0.092	Dicapthon		Fenitrothion	2.80
0.100	Malathion			
			Malathion	4.3
0.230	Propoxur		Dicapthon	6.9
0.300	Promecarb			
			Abate	16.0

Figure 1. Cumulative mortality of susceptible and proposur-resistant larvae of *C. quinquefasciatus* at various time intervals during continuous exposure to propoxur (Baygon) and carbofuran (Furadan). (After Shrivastava et al. 1970)

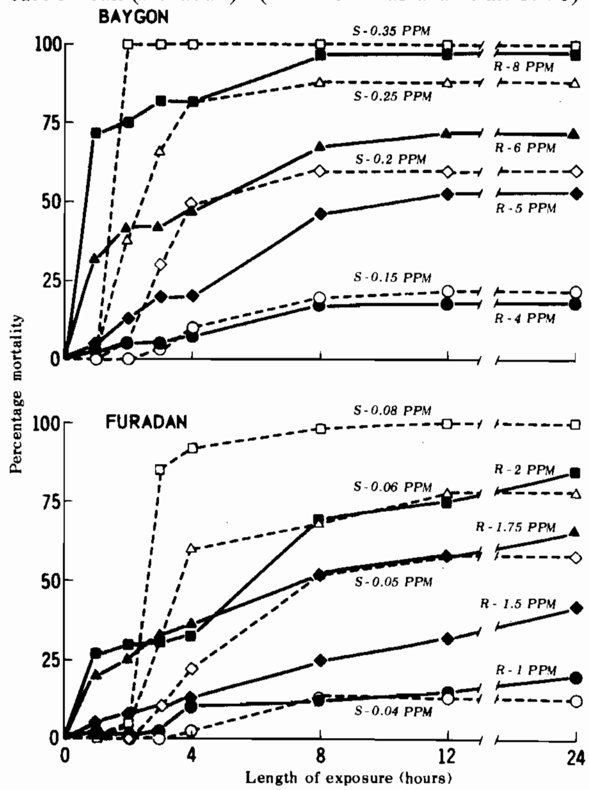
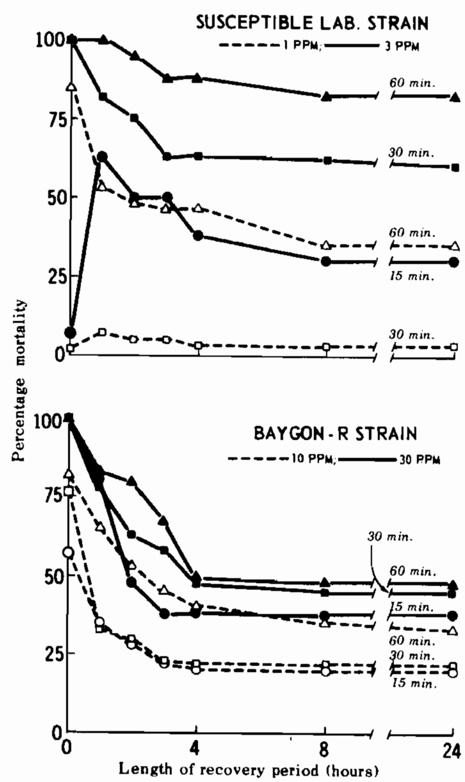


Figure 2. Recovery of susceptible and propoxur-resistant larvae of *C. quinquefasciatus* at various time intervals following short-term exposure to propoxur (Baygon). (After Shrivastava et al. 1970)



knockdown. But if an organophosphorous insecticide is used instead, no recovery occurs because the latter inhibits cholinesterase, irreversibly. This rather simplistic interpretation touches on only a few of the factors influencing net toxicity. It is recognized that many other factors contribute significantly and that their interactions are complex (Winteringham 1969).

Since the performance of an insecticide in each life stage is influenced by several dynamic factors, the question may then be asked whether the development of resistance in one stage, such as the larvae, would be accompanied by an equivalent degree of resistance in the adult stage. The answer depends on which factors are responsible for resistance. We now have sufficient evidence that an increase in the efficacy of a metabolizing enzyme in larvae is accompanied by roughly the same increase in adults. Thus, if resistance is due to metabolism, alone, both larvae and adults would be expected to be about equally resistant. However, although metabolism is indeed the primary mechanism of resistance in most of the cases so far examined, other mechanisms are known to exist, which in certain instances have a profound influence on the observed level of resistance. For example, a two-fold reduction in the rate of penetration of the insecticide into the insect may enable the metabolizing enzyme to cope with considerably larger doses of the insecticide in the environment; thus, the insect manifests a much higher level of resistance. Evidence is available, also, that reduced penetration into larvae does not necessarily mean reduced penetration into adults, and vice versa. Reduction in cuticular penetration appears to be confined largely to the specific life stage of the insect against which selection pressure has been directed. Thus, in a strain selected with propoxur in the larval stage, the larvae were more resistant than the adults, while in a sister strain selected in the adult stage, the adults were more resistant than the larvae (Figure 3). However, when both the larval and the adult stages of a strain were selected, resistance of nearly equal magnitude developed in both life stages (Table 2).

The evidence cited indicates that it is possible to have unequal degrees of resistance in larvae and adults if the two life stages have been subjected to distinctly different degrees of selection pressure. We recently had the opportunity to examine this question under field conditions in connection with resistance in *Culex tarsalis* (Georghiou et al. 1969). Reported failures of commonly used larvicides to give control in certain areas raised the possibility that direct treatment of adults might become necessary if these had moved into residential areas; furthermore, the question arose whether adult field populations of this insect were resistant to the same insecticides as their larvae. Table 3 indicates the degree of resistance in larvae of *C. tarsalis* from the Melga Reservoir area, San Joaquin Valley, as compared with the average susceptibility of larvae from uncontrolled areas lying outside the boundaries of mosquito abatement districts. The susceptibility of adult *C. tarsalis* from the Melga Reservoir area is shown in Table 4. In the absence of adequate numbers of adults from uncontrolled areas, the resistance levels were calculated with reference to a laboratory strain, which had been reared under insecticide-free conditions since 1956. It is obvious from these tests that

Figure 3. Comparative resistance to propoxur in larvae (top) and adults (bottom) of strains of *C. quinquefasciatus* selected by propoxur pressure in the larval (strain Propoxur-L) and adult (strain Propoxur-A) stages. (Adapted from Georghiou et al. 1966)

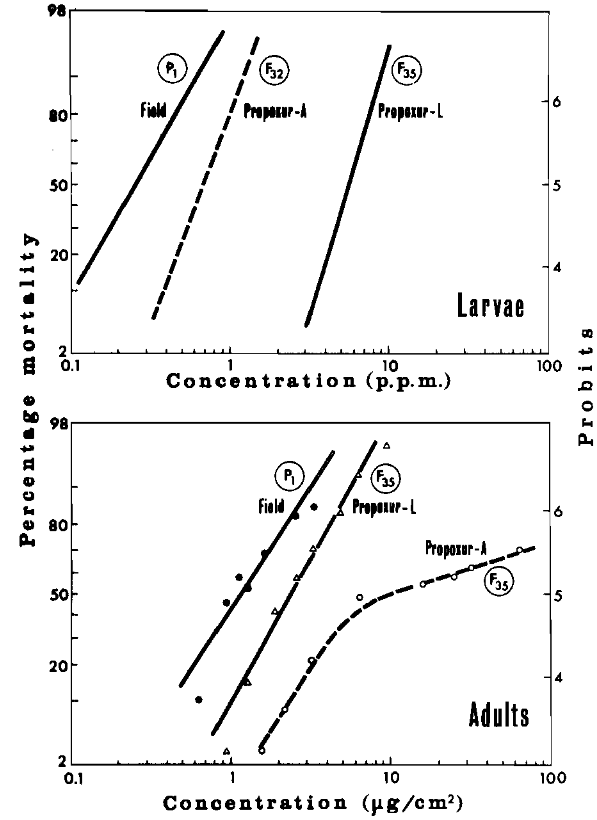


Table 2. Changes in susceptibility in *Anopheles albimanus* (Haiti) selected with propoxur[1]

Compound	Suscept. (P_1)	Selected	Resistance Ratio
	LC_{50} (ppm) Larvae		
Propoxur	0.355	1.04 (F_{30})	3.0
Carbofuran	0.207	0.27 (F_{31})	1.3
Malathion	0.322	0.277 (F_{30})	0.9
Fenthion	0.028	6.028 (F_{30})	1.0
Fenitrothion	0.046	0.051 (F_{20})	1.1
	LC_{50} (ppm) Adults		
Propoxur	0.38	1.32 (F_{24})	3.5

1 Georghiou 1969

Table 3. *Culex tarsalis:* Comparison of LC_{95} values of larvae from susceptible (uncontrolled) and resistant (Melga Reservoir) areas[1]

	Susceptible		Resistant		
Insecticides	LC_{95}	Slope	LC_{95}	Slope	R/S
Malathion	.074	4.1	13.59	1.2	183.6
Parathion	.0051	4.4	.080	3.3	15.7
me-Parathion	.0061	5.0	.097	2.4	15.9
Fenthion	.0067	4.7	.056	3.1	8.4
Dursban	.0012	3.8	.054	1.9	45.0
Abate	.00067	6.1	.023	2.4	34.3

[1] (Georghiou et al. 1969)

Table 4. *Culex tarsalis:* Comparison of LC_{95} values of adults from susceptible (lab.) and resistant (field, Melga) populations[1]

	LC_{95} (microgram/cm^2)		
Insecticides	Susceptible	Resistant	R/S
Abate	2640.	)5000.	∞
Malathion	60.8	3072.	50.5
Fenthion	.86	56.	65.1
Dursban	.3	10.9	36.3
Naled	1.15	2.4	2.1
Dichlorvos	.4	.67	1.7
Propoxur	.51	1.47	2.9

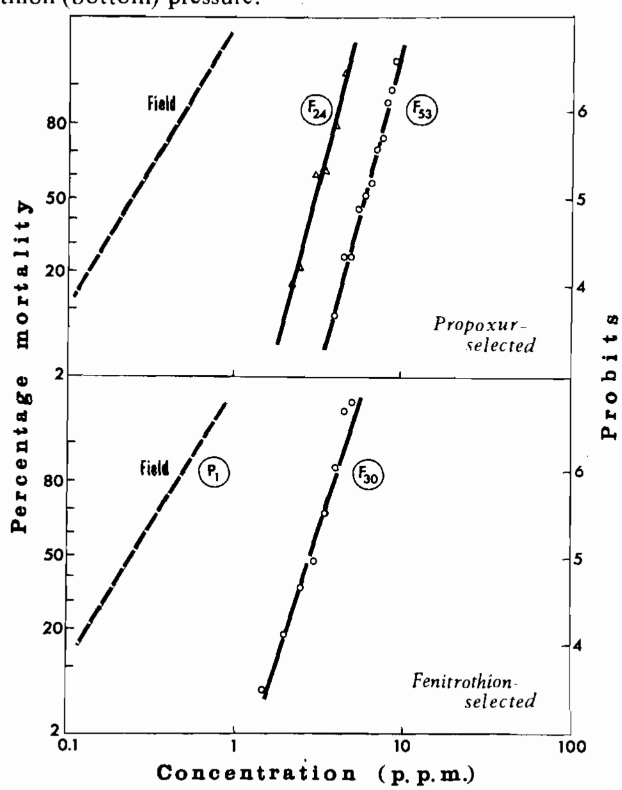
[1] (Georghiou et al. 1969)

both larvae and adults of the Melga strain are highly resistant to Abate, malathion, fenthion and Dursban. A comparison between the adults of this laboratory strain and the field strain was evidently valid, since only a small difference was noted in their susceptibility to three compounds that have not yet been used extensively for mosquito control in California, namely, naled, dichlorvos and propoxur. These comparisons of larval and adult resistance indicate that under the conditions prevailing in California, insecticide use has operated against both life stages of this species.

Since the question of resistance in *C. tarsalis* has occupied our thoughts throughout this meeting, I shall now attempt, very briefly, to provide some recommendations for a future course of action. Beyond any doubt, an ecological approach to the problem of mosquito control is overdue. The more limited the use of insecticides, the slower the rate of development of resistance. But until we know more about the insect and its interaction with the environment, we are forced to depend largely on the judicious use of insecticides in the general context of integrated control. Concerning the choice of suitable insecticides, may I suggest that we continue, as long as possible, to use organophosphates rather than to change to carbamates. Available data indicate that the degree of resistance in *C. tarsalis* varies from one area to another. Fenthion, methyl parathion, EPN, Dursban and Abate continue to be effective in many localities. It would be unwise, I believe, not to exhaust the usefulness of these materials before moving on to the carbamates; such a move would open the door for resistance to this group of insecticides, as well.

I might also venture the prediction that the period of usefulness of carbamates, when they are used against organophosphorus-resistant populations, will be rather short: cross-resistance at various levels does occur between organophosphates and carbamates. For example, selection with fenitrothion produced a high level of resistance to proposur, almost as high as that produced by selection with proposur itself (Georghiou and Calman 1969) (Figure 4). And when resistance to carbamates does develop, it is not confined to the selecting carbamate alone but extends to a variety of structurally related compounds (Georghiou et al. 1966).

Figure 4. Larval resistance to propoxur in strains of *C. quinquefasciatus* selected by propoxur (top) and fenitrothion (bottom) pressure.



Therefore, let us limit the use of insecticides to a degree of absolute necessity. And while we still continue our search for more specific, biodegradable. less hazardous insecticides, let us intensify our efforts to understand the insect and its environment. We shall be more successful in the long run.

References Cited

Georghiou, G.P. 1969. The resistance potential of anopheline and culicine mosquitoes to cholinesterase inhibitors. World Rev. Pest Control. 8:86-94.

Georghiou, G.P., and J.R. Calman. 1969. Results of fenitrothion selection of *Culex pipiens fatigans* Wied. and *Anopheles albimanus* Wied. Bull. Wld. Hlth. Org. 40:97-101.

Georghiou, G.P., P.A. Gillies, and D.J. Womeldorf. 1969. *Culex tarsalis* Coquillet: Detection of resistance to parathion, methyl parathion, fenthion, Dursban and Abate in a malathion-resistant population. Calif. Vector Views. 16:115-118.

Georghiou, G.P., R.L. Metcalf, and Frances E. Gidden. 1966. Carbamate-resistance in mosquitoes. Selection of *Culex pipiens fatigans* Wiedemann (= *C. quinquefasciatus* Say) for resistance to Baygon. Bull. Wld. Hlth. Org. 35:691-708.

Shrivastava, S.P., G.P. Georghiou, R.L. Metcalf, and T.R. Fukuto. 1970. Carbamate-resistance in mosquitoes. II. The metabolism of propoxur by susceptible and resistant *Culex pipiens fatigans* Wied. larvae. Bull. Wld. Hlth. Org. (In press)

Winteringham, F.P.W. 1969. Mechanisms of selective insecticidal action. Ann. Rev. Entomol. 14:409-442.

FURTHER RESEARCH RELATING TO MOSQUITO RESISTANCE

Mir S. Mulla
Department of Entomology, University of California, Riverside

The need for increased research to cope with the problem of resistance in California mosquitoes is much greater today than ever before. The picture painted before us here by the panel members looks rather grim. Not only are we faced with the problem of development of resistance to materials used in operational programs, but the problem is much more aggravated by the simultaneous appearance of cross-tolerance in both the pasture mosquito (*Aedes nigromaculis* Ludlow) and the encephalitis mosquito (*Culex tarsalis* Coq.) in the Central Valley to materials scarcely used in mosquito suppression programs in California. In view of these recent developments during the 1969 season, we should take a new look at planning both our research as well as actual operational activities. Research should be aimed toward finding diverse methodologies and these methodologies when developed and perfected should be employed whereever practical.

It should be emphasized that research and researchers are not in a position to find and develop a single-shot approach to the varied mosquito problems in California. Development of an ideal material which costs little, yet kills all susceptible and resistant mosquitoes, can be applied at 4-6 oz. per acre, and yet not cause drift problems, is non-phytotoxic, safe to applicators and non-target organisms and one which can be used everywhere, is out of the question. Similarly, finding of a pathogen or other biotic control agents with all the desired attributes is beyond our present capabilities. It therefore becomes imperative that all avenues and all possibilities be explored for developing an integrated and coordinated mosquito control technology.

Let me point out that if we have to control mosquitoes, the use of synthetic or naturally occurring compounds will play a major role in the suppression programs of both pest and vector mosquitoes. However, it should be borne in mind that non-chemical methods of control should be fully investigated and utilized in conjunction with chemical methods, whenever possible. An outline of possible research areas pertaining to the ever-increasing problem of resistance development in some of our widely distributed mosquitoes is presented below. This outline is by no means all-inclusive, but suggests some important areas of needed research.

A. – Threshold Populations

Mosquito control in California is mainly directed against the larvae. The threshold larval population density corresponding to a threshold adult population has not been established. The threshold population density will, of course, vary from place to place or according to circumstances. The relationship between larval density and adult production in mosquitoes breeding in impoundments is influenced by numerous factors. For example, heavy populations of 1st to 3rd instar larvae of *C. tarsalis* may not yield large populations of adults in situations where predaceous fish or invertebrates are prevalent in the breeding source. In such a case, the prevalence of the pupal stage might be a good index of adult emergence.

The application of chemical larvicides to any type of breeding source harboring young larvae is not a sound approach to the control of impoundment mosquitoes. Studies are needed to establish the efficacy of such treatments on the yield of adult mosquitoes rather than against the larval populations. Based on preliminary data, it is very likely that not all sources harboring larvae will yield significant numbers of adult mosquitoes. A reduction in the number of mosquito breeding sources treated with larvicides will eventually result in avoiding unnecessary cost and possibly delay in the development of resistance.

B. – Surveillance and Characterization of Resistance

In order to predict the efficacy of newly developed materials, it is desirable to study the cross-tolerance pattern of resistant strains. Failures of currently employed compounds may be either due to the appearance of resistance or due to factors beyond the control of the applicator. To rule out the influence of these factors, level of resistance in the hard-hit areas of the state should be monitored.

C. – Screening of New Materials

Even though we might be able to develop and formulate appropriate oil-amine formulations, it is still problematic to employ these formulations under many varied conditions. Through regular laboratory and field screening programs it is very likely that we might be able to find effective compounds which will be active against resistant strains, or have a different mode of action against mosquitoes than those materials which have been and are being used in mosquito control programs in California. It is therefore necessary that the initial laboratory and field screening programs be expanded with the objectives of finding effective materials against a number of species of California mosquitoes.

D. – Resistance-Proof Chemicals

Since the three major classes (organochlorine, organophosphate and organocarbamate) of insecticides are prone to the development of resistance, studies on the development of materials which are potentially resistance-proof should be vigorously pursued. It is imperative that we have such a chemical in our arsenal, even though we might be inclined to use some of the more modern and quite effective materials belonging to the organophosphate or organocarbamate class of compounds. The use of petroleum oils, aliphatic amines and some of the botanicals merits serious consideration. Petroleum oils and aliphatic amines offer the best possibilities for use in situations where resistance to modern synthetic materials is a perennial problem. The oils and amines do not have the same mode of action as modern synthetic insecticides and are not subject to cross-tolerance. Field evaluation of these against both resistant *C. tarsalis* and *A. nigromaculis* should be accomplished. Development of appropriate formulation and application equipment should attract attention. Once this methodology is developed, it can be relied upon whenever the development of resistance to the other insecticides disrupts operational programs.

E. – Habitat Management

Habitat management should involve alteration of the breeding or resting sites in such a manner that they are compatible with wildlife and farming practices. Source elimination utilizing drainage and drying up of wetlands is undesirable from the standpoint of conservation and wildlife interests.

One area of research involves investigation of the relationship of pasture management to mosquito production. In irrigated pastures, water management through reduced water usage and increased water percolation may result in the production of fewer mosquitoes. Similarly, close grazing of the forage by animals or mowing of the grass may result in open pastures which are less productive as far as mosquitoes are concerned. In such pastures, chemical treatments are likely to be more effective due to increased penetration by droplets or granules of the sparse and short plant cover.

F. – Development of Compounds from Biological Sources

Compounds produced or derived from biological agents such as algal toxins, bacterial toxins, oviposition attractants, overcrowding factors, mucilaginous seeds and other active compounds of biological origin should be actively researched. The potential use and commercial exploitation of such compounds should be investigated beyond the laboratory stage.

Recently, several such discoveries have been made in our laboratories on the Riverside Campus. Semi-field and field evaluation of these substances will shed light on the commercialization of such compounds. Due to the complex nature of these compounds, much research and efforts are needed to develop these substances for possible use in mosquito control programs.

G. – Studies on the Role of Biotic Control Agents

There is no doubt that a variety of invertebrate and vertebrate biotic control agents play a major role in the regulation of our mosquitoes breeding in permanent to semipermanent bodies of water. An understanding of the complex interrelationships among these agents and mosquitoes will provide a basis for the formulation of an efficient integrated mosquito control technology. The role of these biotic agents in the regulation of mosquito as well as nontarget populations should be fully investigated.

INTER–RELATIONSHIP OF CMCA, AMCA AND DISTRICTS

W. D. Murray
Delta Mosquito Abatement District, Visalia

The Tulare Union High School annually holds a series of forum programs directed especially to teachers and parents, but all people of the community are urged to attend. Approximately 1,000 adults attend these meetings. At a recent meeting, an excellent film was presented on birds and other non-human wildlife along the California coast from San Francisco to Big Sur. The speaker repeatedly referred to the damage caused by pesticides to these animals. He stated, further, that pelicans had already been exterminated along the Gulf coast as a result of pesticides used in that area.

A long time resident of the Gulf coast area has stated to me that pelicans did occur there and that they were now extinct. But he stated that a hurricane about 1948 wiped out their restricted breeding grounds, and that insecticides had nothing to do with their demise. Many speakers and writers who have expressed opposition to pesticides have been stating partial truths, misinformation, or outright falsehoods. A news release in November, 1969, quoted a Tulare County doctor as claiming that, of 58 children tested in that county, 27 showed signs of poisoning by organic phosphate pesticides. This doctor would not wait for a scientific analysis of the tests but was anxious to obtain publicity. Therefore he must be accused of issuing lies. An analytical study showed that no children were affected by phosphate insecticides. Newspaper reporters on occasion may be equally guilty, since they apparently have a legal right to make statements without any responsibility for producing supporting facts.

Leadership is very important in this struggle. Dramatic leaders may gather a large following, even though they may express only partial truths and may actually lead their naive followers down a road to destruction, as occurred in the case of Hitler. Some of the antipesticide leaders are just as vicious and just as dangerous. Life is a competitive struggle, and the CMCA must take an aggressive position to disseminate a true story which will assure the best interests of the people. Our present population explosion is not the result of an increasing birth rate, but rather the dramatic saving of lives through the use of chemicals such as DDT and other insecticides for the control of human and crop pests, and such as penicillin for the control of bacteria, etc. How do we combat the antagonists and present the truths? Education! The dispersal of information in all useful, available ways!

Unfortunately, some of what has been provided to the public has contained errors, due either to lack of knowledge or to an inertia on the part of authors to look up the facts. The California State Text for the 6th grade, "Keeping Healthy", states: " ..the mosquito lays many millions of eggs in a few months. She lays her eggs in quiet, stagnant water. That kind of water is usually dirty and full of filth." But a female mosquito cannot lay more than a few hundred eggs in a life time; the mosquito against which the greatest control effort is waged in California lays its eggs on mud, never on water; and most mosquitoes in California spend their larval stages in reasonable clean water. Another paragraph in this text is entitled "How the Mosquito Spreads Bacteria." It states: "When a mosquito bites a person, a few drops of blood are sucked into its body. If these few drops of blood have disease-producing bacteria in them, the next person the mosquito bites will receive some of these bacteria into his blood." Although the mosquito has been demonstrated to be a vector of many viruses, protozoa and worms, it has never been charged with spreading disease-producing bacteria. How can students have respect for the words of "authorities" if these authorities state so many errors of fact?

There is a need for accurate, effective communication to the public, and especially to students. Local control districts should help, but support from CMCA and AMCA is essential. Certainly there is greater need than ever for a good, coordinating and information-dispensing central office, both in CMCA and AMCA.

AMCA established a new committee in 1968 – World-wide Mosquito/Vector Control Program Liaison Committee – to fill the need for an internationally-oriented organization to aid in the dissemination of information on mosquito and vector control throughout the World.

The CMCA has taken steps to provide a more useful, more active central office. Certain basic printing equipment has been obtained, and many items which could not be produced in the past because of a lack of funds or direction should be produced in the future. The continuing production from this office should demonstrate the wisdom of the steps taken. All trustees and mosquito control workers should join in a positive leadership so that the united voice of all will be effective in producing better world-wide vector control.

1969 CMCA LEGISLATIVE COMMITTEE REPORT

James W. Bristow
Southeast Mosquito Abatement District, South Gate

The Legislative Committee of the California Mosquito Control Association completed the following Legislative Program in 1969. Several Legislative Bills sponsored by the CMCA were approved by the Legislature and signed by the Governor and are now law of California.

1. Assembly Bill 121 which involves the increase of Trustees' in-lieu expenses from $25 to $35 was signed by the Governor April 22, 1969 and went into effect November 10, 1969. This legislation applied only to mosquito abatement districts and not to pest abatement districts. It would appear that legislation might be introduced to equalize maximum of in-lieu expenses. The 1970 Legislative Committee should explore the desires of the pest abatement districts.

2. Senate Bill 126 which involves state responsibility for nuisances on state land was passed. This Bill was amended to meet objections of certain state agencies and with the approval of the CMCA. In any case, state agencies are responsible for controlling mosquitoes on state lands when required with the State Health Department as the arbiter of required work. William Hazeltine is to be congratulated for the principal work on this legislation.

3. Usage of Injurious Materials (Insecticides) and Injurious Herbicides reporting required. This legislation was not opposed by the CMCA since it was felt that information of this type would be helpful to all concerned whether Government, conservation, or other parties.

4. Senate Bill 1430. This was popularly known as the Nejedly Bill or Anti-DDT Bill. The CMCA opposed this Bill originally due to grave weaknesses in the original Bill and because it was convinced that the sponsors of this legislation approached the subject from an emotional standpoint rather than from a well reasoned standpoint. The Bill passed the Senate, but was defeated in the Assembly. This type of legislation is emotionally satisfying to a great number of Legislators and is most popular with the people in general. Every effort should be made that opposition from the standpoint of the CMCA be carefully handled to the end that a minimum undesirable impact be made on all Legislators.

5. Assembly Bill 325 – Disclosure of Assets. This legislation, known as the Unruh Bill, was passed by the Legislature and signed by the Governor. As of now, it would appear that Trustees of all districts would have to file a dis-

closure of their assets in accordance with the law prior to April 15, 1970. Legislation has been proposed in the current meeting of the Legislature to pass an emergency measure modifying last year's legislation.

6. CMCA Research Committee Members, Gordon Smith and Melvin Oldham, have had Bills introduced by Senator Marler for Research Fund implementations for the University of California, College of Agricultural Sciences, and the UC School of Public Health Arbovirus Field Stations, as well as a companion Bill to provide additional supportive positions for the Bureau of Vector Control. The 1970 Legislative Committee will work on this legislation and obtain legislator co-sponsors.

7. Assembly Bill 988. This Bill prohibits the discharge in the atmosphere of specific air contaminants by aircraft for a period of over 10 seconds in any one hour. There was some question whether this would affect spray operations by mosquito abatement districts. The intent of the Bill was to regulate the discharge of smokey exhaust by commercial aircraft approaching airports. Assurance was given that the Bill would not affect spray operations of mosquito abatement agencies. The Bill was passed and is now law.

8. Additional Bills of interest include the following that are now law.

a. Sanitarian registration fee – SB 402 (Chapter 267), Sherman. Requires applicants for sanitarian certification examination to pay a nonreturnable $15 fee for each such examination.

b. Water quality – AB 412 (Chapter 800), Porter. Makes technical corrections, clarifications and additions to the Water Quality Control Act of 1969 (AB 413).

c. Water quality – AB 413 (Chapter 482), Porter. Revises generally laws governing water quality and water pollution control. Appropriates $84,000 to State Water Resources Control Board for purpose of act. Operative January 1, 1970.

d. California Conference of Local Health Officers – AB 997 (Chapter 545), Fong. Authorizes the California Conference of Local Health Officers to consult with, advise, and make recommendations to prescribed governmental and other bodies and officials in addition to the State Department of Public Health as previously limited.

e. Pesticides – AB 1209 (Chapter 1413), Patee. Provides that before pesticide application is made, the applicator shall be in possession of written recommendation.

I would also like to add that all Trustees are urged to maintain a good climate of trust and friendship with their local legislators. In this way legitimate needs in the public interest of mosquito control agencies are more likely to be supported by our state legislative bodies.

In conclusion, the Chairman wishes to thank the members of the Legislative Committee for their interest and support and work on the Committee and for the fine backing received from the Board of Directors and membership of the CMCA.

IN–SERVICE TRAINING PROGRAM

Richard F. Peters
Bureau of Vector Control and Solid Waste Management
California State Department of Public Health

A concern has been expressed at each recent Conference that the training area in mosquito control is not adequately met by the local programs. The Bureau of Vector Control (BVC), which was formed in 1947, was charged with a responsibility to assist local mosquito control agencies through a subvention program. Although the subvention program dwindled and finally was eliminated, it nevertheless did help develop many of the local mosquito abatement agencies. In 1946 there were only about 30 agencies in California, covering about 5,000 square miles, while today there are over 60 agencies covering over 40,000 square miles.

In the late 1940's and early 1950's the Bureau of Vector Control conducted a rather intensive type of in-service training program. During that time, and since then, many developments have occurred in this field. By 1952, the mosquitoes developed a high level of resistance to the chlorinated hydrocarbon insecticides. A big water year and mild spring favored very high populations of *Culex tarsalis* and a real outbreak of encephalitis ensued, with over 800 reported cases and 50 deaths. At the present time mosquitoes are demonstrating a high resistance to organophosphorus insecticides. Also, a wave of public sentiment today concerning the environment may cause such questions to be asked any one of your agency operators: "Are you here to poison me and my family?" or "Are you here to keep my family from getting encephalitis?"

The slanted newspaper coverage about pesticides and the general failure to present to the public complete, well documented information and evaluation of the pesticide problem, will require local staffs to possess technically correct facts ready for dissemination to all who should be informed. But what about these staffs? At present there is no formal training program prerequisite for mosquito control personnel; therefore, young men must be trained on the job to obtain skills for their tasks. The Bureau of Vector Control and the local mosquito control agencies should share responsibility for a good in-service training program. No one should doubt that more attention must be given to this matter than has been done in the past.

Another aspect of this question has become increasingly important, as indicated by political activities in Contra Costa and Fresno counties. There are some who ask "Are mosquito abatement districts really necessary after all?" or "Would it be better to have all activities of this type under the direct control of the county supervisors?" In Contra

Costa County a strong effort was made by the executive officer of the Local Agency Formation Commission, stimulated by the Board of Supervisors, to dissolve the Contra Costa Mosquito Abatement District and to seek to carry out mosquito control in the future through another unit of county government. The Board of Trustees did not concur with this, repudiating the move 10 to 2.

Mosquito abatement districts will be expected to perform broader programs than mosquito control, if indeed they are to endure. They cannot afford to be regarded as a luxury political subdivision. Many districts are already also doing gnat (midge) control, and some have begun to do wasp control; both are perfectly legal. The wording of the original law would not have been written empowering the "control of mosquitoes, flies and other insects" if the legislature had not so intended. A mosquito abatement district formed since 1931 may also control rats if a separate tax is assessed for this purpose.

One message of the Contra Costa County Board of Supervisors was clearly presented "We cannot afford a single purpose agency that is not sufficiently flexible to handle other problems affecting the public." Mosquito abatement district staffs must be prepared to carry out control of such other public vector problems as the public may request, and to do them economically and effectively. Thus, this expanded control need is a part of the in-service training need.

IN–SERVICE TRAINING IN CALIFORNIA'S MOSQUITO ABATEMENT DISTRICTS

Thomas D. Peck
Bureau of Vector Control and Solid Waste Management
California State Department of Public Health, Berkeley

In-service training programs have immediate goals and long-range goals. Immediate goals deal with specifics, such as handling equipment and mixing pesticides. The training for immediate goals has been relatively easy because of the exceptionally high level of technical competence within the management of the CMCA. I say "relatively easy" since immediate goals usually deal with technical competencies that can be measured. If performance is inadequate, training can be modified to achieve the measure of success desired.

Successful training for long-range goals is more difficult to attain. It involves long-range planning, personal and public attitudes, and even political considerations. During the last few years the Bureau of Vector Control and Solid Waste Management has received many requests for a thorough, well planned, long-range vector control training program. As the changes which are occurring in our social and ecological environment become more noticeable, so do the requests.

Since planning is best accomplished with a knowledge of past activities, a questionnaire was sent to mosquito abatement district managers to ask about their training programs. I should like to take a few moments to acquaint you with the answers they gave us.

Question No. 1 was, "How much training has your staff participated in during the last four years?" Formal training sessions, those which involve instructors other than district personnel and for which special time is set aside, averaged a little less than one per year per district. In addition to this, most managers indicated that some time was given to training in staff meetings. Some districts have weekly staff meetings and devote some time to training at nearly every meeting, other districts include training in staff meetings "during winter months", and some "when needed". There were also occasional sessions when an industry representative was given time to discuss some special phase of control which involved his field.

The subjects most frequently discussed were mosquito biology and identification, pesticides, source reduction and safety. Subjects mentioned less often were insecticide resistance, weed control, mapping, equipment operations and public relations. The instructors for the training were the mosquito abatement district managers and entomologists, the staffs of the State Department of Public Health and the University of California and occasional representatives from industry.

Question No. 2 asked, "Was the in-service training really useful, and what were its good and bad points?" This question was too subjective and the answers were not specifically helpful. The majority of the managers indicated that they favored training programs (just like motherhood) but I was not able to establish an overall trend except for the need for training programs.

Question No. 3 asked, "Would you like to have additional training programs within the next year or two, and if so, on what, where, and when?" The answers to this question gave us a definite overall trend. Several managers made emphatic requests for more training and most indicated that they would give support and priority to a well organized training program. Their opinions varied considerably on how and by whom the training should be given. One manager declared that training should be the responsibility of managers and boards of trustees of the mosquito abatement districts, that the personnel of state health agencies and the universities should function as technical specialists by request, and they should do little else. At the other end of the scale, one manager said that the Bureau of Vector Control and Solid Waste Management should start a statewide training program, develop a syllabus for it, and ultimately develop a certification program which would include testing and registration. He felt that a program of this kind would give mosquito abatement personnel a higher stature in the eyes of the public.

Most answers fell between these extremes, but with an obvious trend towards our Bureau taking the initiative in developing and conducting a comprehensive statewide training program with the close cooperation and guidance of mosquito abatement district managers.

While the answers to the questionnaire did not provide any simple solutions to our problems, they confirmed our suspicions (which caused us to circulate the questionnaire in the first place) that the majority of mosquito abatement district managers strongly feel the need for better and broader based training.

My overall impression is that while the association has conducted a fairly adequate type of training program in the past, it is no longer giving us an acceptable return on our investment, and certainly will not do so in the future, owing to the many social and technical changes we face.

HOW THE ORANGE COUNTY MOSQUITO ABATEMENT DISTRICT CONDUCTS IN–SERVICE TRAINING

Jack H. Kimball
Orange County Mosquito Abatement District, Santa Ana

Training within the Orange County Mosquito Abatement District has been accomplished by exposure, involvement and participation in all affairs that are or should be of concern and interest and which affect the economic security, the future advancement, and the personal well-being of the employees.

In-service training to expand employee skills cannot be truly effective until management has first established specific personnel policies and procedures which recognize the employee's need and desire for economic security, future advancement and for his own well-being and that of his family. The District's Board of Trustees is responsible for adopting the basic personnel policies which authorize management to carry out a complete program. Orange County has tried to fulfill this responsibility by developing a personnel program made up of the following elements:

I – Economic Security of Employees

It is necessary that management encourage and assist the employees to join and participate in an organization or union of their choice which represents their economic interests. In our case the organization is the Orange County Employees Association.

1. Encourage 100% membership in their Association.
2. Encourage the employees to be well informed on all candidates nominated for the various offices of their Association and to carry out their voting responsibilities.
3. Provide the time and place for the employees to select their own representative to the Association's Advisory Council.
4. Encourage regular attendance by the employee's representative of the Advisory Council meetings and provide the time and place for his report to the employees on Association affairs.
5. Provide information on annual salary surveys by their Association as well as by other agencies and organizations.
6. Keep the employees informed on negotiations by management for salaries and employee benefits.

II – Future Advancement for Employee

It is necessary that management be concerned with the future advancement of each employee by providing information on job opportunities and by making available technical and professional information that may help him improve his knowledge on the job requirements.

1. Provide description and qualifications for all District positions.
2. Schedule annual job performance evaluations of all employees.
3. Provide competitive examinations for qualified District employees.
4. Maintain a reference library for employees who wish to study for advancement. Such a library should provide the following:
   (a) California Mosquito Control Association, Proceedings and Publications.
   (b) American Mosquito Control Association, "Mosquito News" and publications.
   (c) Reprints of articles from other publications.
   (d) California's State Health Department publication, "Vector Views" and "California's Health".
   (e) Annual and monthly reports from other mosquito abatement districts.
   (f) Current newspaper and magazine clippings.
   (g) Reference material prepared by the District.
      (1) Employee's Reference Manual.
      (2) Mosquito Control Encyclopedia.

III – Well-being of Employee and His Family

It is management's responsibility to provide information on services available to the employee which will assist him in providing his family a measure of security in the event of a major medical expense or accidental death. Our employees may purchase five types of insurance through their Employee's Association. The rates are very low because the Employee's Association has over 6,000 members. District policy provides for automatic salary deduction in the usual manner. The Orange County Employee's Credit Union provides, through our payroll deduction plan, the opportunity for automatic savings at favorable interest earnings as well as for loans at minimum interest charges. The District provides a retirement plan and a fully paid major medical insurance plan for each employee. The employee may purchase additional major medical coverage for his family.

It is important that management keep the employees advised on all services available and to assist him in making out the various application forms as well as his claims for reimbursement. These services, including benefits furnished by the District are itemized below.

1. Employee Retirement Program
2. Employee & Family Health Program

3. Life Insurance
4. Salary Continuance Insurance
5. Automobile Insurance
6. Accidental Death & Dismemberment Insurance
7. Dental Health Insurance
8. Employee's Credit Union

IV – Expanding Employee Skills

The mosquito control operator must be technically informed and trained in many skills. Employees are receptive to training and are interested in learning new skills and related information on mosquito control only if they feel that management is concerned with and looking out for their security, their future advancement and their personal well-being and that of their family. Our District has established a personnel program which recognizes and provides these necessary elements.

In-service training is conducted on a continuous informal basis throughout the year. In addition the conventional classroom-type training sessions are necessary to review standard operational procedures and techniques as well as to introduce new materials, methods, and equipment and the new techniques by which they are to be used in our mosquito abatement and control program. The services of the Bureau of Vector Control, State Department of Public Health are used whenever available to present training on specialized programs. It is hoped that these services by the Bureau of Vector Control can be expanded in the future to help meet our need for information on new insecticides and methods to control mosquitoes as well as other insects of concern to the District.

Our informal training program which we conduct on a continuous basis is best illustrated by the following list of reference materials and activities planned by management to provide opportunities to the employees for exposure, involvement and participation in all affairs that are or should be of concern and interest to them.

1. Employees Reference Manual.
2. Annual work assignment and instructions for zone operation.
3. Informal Staff Meetings to:
   (a) Review actions and policies by the Board of Trustees.
   (b) Review slides of current operations.
   (c) Hear reports on meetings attended and coming events.
   (d) Review clarification of operational procedures and problems.
   (e) Hear reports on Employee's Association programs.
   (f) Celebrate an employee's birthday (he furnishes donuts).
   (g) To hold a "Kangaroo Court" for "goofs" and/or accident by employee (he furnishes donuts).
4. Employee contact with employees of adjoining districts.
5. Participation in Regional Mosquito Control Meetings.
6. Attendance and participation in CMCA Annual Conference by all operational personnel when held in our region.
7. Orientation and working relationship with other public agencies.
8. Direct contact with Area Representative of the State Bureau of Vector Control the State Fish and Game Department, with research workers from university and college campuses, and with visitors from foreign countries to observe our program.
9. Attend Annual Training Courses in Radiological Defense and Natural Disasters.
10. Participation in field test of new materials, methods and equipment.
11. Preparing written reports on field observation and conclusions.
12. Presentation of operational reports before Regional Meetings and Annual Conferences of this Association.

For a mosquito abatement program to be effective each employee, especially the control operator working in the field, must be motivated. He must know that his job is important, no matter how simple or routine it may be. He must like his job and feel that he is a vital part of the entire program. To do his job well he must be technically trained on what he is doing and well informed on why he is doing it. He must be responsible, and use good judgment when making decisions in the field.

For a mosquito abatement program to be a success, especially in an urban area, all employees, from the telephone operator to the control operator must be able to meet the public as an official representative of the district. He must be able to gain the respect of the public by his sincere recognition of the requester's problem, and by his knowledge of the local environment which can produce mosquitoes or other insects as the case may be. He must be able to inform the public on what the district is doing or will do or will not do. Most important, he must teach the public how to prevent mosquitoes from breeding on individual premises, whether it be a residential back yard, an agricultural operation, industry, or a public owned facility.

Orange County's in-service training program is designed to produce employees who can and will accomplish the objectives of our Mosquito Abatement program, which I quote as follows: "To abate existing mosquito breeding sources and to prevent new ones in order to permit full use and enjoyment of our back yards and our many recreational facilities; to permit mosquito free agricultural and industrial working conditions, and to protect public health and comfort."

WHAT COULD BE THE FUTURE PROGRAM

Richard F. Peters
Bureau of Vector Control and Solid Waste Management
California State Department of Public Health, Berkeley

In our role at the state level we shall proceed to establish greater responsibility of providing in-service training for those agencies that would like such a resource. Any kind of training program with which we might proceed will be a voluntary program, without imposition of any mandates. We have very capable staffs, which would function through the five regional offices of Redding, Sacramento, Berkeley, Fresno and Los Angeles. In the future we are planning to prepare a syllabus that will be available as part of the training program. Ultimately the training may reach the certification level so that district employees may take an examination and receive a certification of competence.

INTER–AGENCY COOPERATION CONTRACTUAL ARRANGEMENTS

Gardner C. McFarland
Southeast Mosquito Abatement District, South Gate

Mosquito control agencies operate in close conjunction with many other agencies and organizations. These include cities, special districts, counties, the state, and federal agencies. Departments of cities that mosquito control agencies work with include street, public works, and parks. Special districts include irrigation, water, park, health. Counties include flood control districts, parks, road, and health. State includes highway, water resources, health, parks, and fish and game. Federal includes corps of engineers and health. The relations among the mosquito control agencies and the various agencies and organizations depend on the mission of each. I will only cover that portion of this subject involving contractual relations whereby the agency or organization contracts with the mosquito abatement agency for mosquito or other vector control.

The Southeast Mosquito Abatement District carried on an intensive program of mosquito and chironomid control throughout its area of jurisdiction. Three agencies in particular are involved in the management of water that breeds mosquitoes and midges that require close correlation: the Los Angeles County Flood Control District, the U.S. Army Corps of Engineers, and the Los Angeles City Bureau of Water and Power. These three agencies manipulate water extensively, both from a flood control and water conservation standpoint.

It was determined early in the history of our District that close coordination of construction, maintenance, and handling of water disposal and percolation was necessary. These three agencies determined that the mission of our Mosquito Abatement District was such that it was to their advantage to have the District give them technical advice as to vector and insect nuisance control and in many cases actually to contract with the District for the control of midges, mosquitoes, and simuliids (Buffalo gnats) (black

A. – Request for Service — S A M P L E —

LOS ANGELES COUNTY FLOOD CONTROL DISTRICT

September 3, 1969

File No. Contract No. 6097
Request for Application of
Insecticide

Mr. Gardner McFarland
Southeast Mosquito Abatement District
9510 South Garfield Avenue
South Gate, California 90280

Dear Sir:

In compliance with Paragraph I of Contract No. 6097 dated September 13, 1962, and Extension of Agreement dated July 8, 1969, this letter will confirm the request made by Mr. C. J. Reinhard on August 29, 1969, for your District to survey Tujunga Wash between Hansen Dam and Orovista Avenue for Buffalo Gnat infestation.

Yours very truly,

Walter J. Wood, Chief Engineer

By Division Engineer, Water Conservation

– S A M P L E –
AGREEMENT

THIS AGREEMENT, made and entered into the 13th day of September, 1962, by and between the LOS ANGELES COUNTY FLOOD CONTROL DISTRICT, a body corporate and politic, party of the first part, hereinafter called "District", and the SOUTHEAST MOSQUITO ABATEMENT DISTRICT, a body corporate and politic, party of the second part, hereinafter called "Mosquito Abatement".

WITNESSETH:

WHEREAS, District desires to provide for the control of various vexatious species of chironomid midges and mosquitoes which can be a source of public nuisance and discomfort in and about District water conservation facilities located in and adjacent to the Montebello Forebay; and

WHEREAS, increasing amounts of imported and reclaimed water will be spread during the warm seasons when insect infestations are more likely to occur; and

WHEREAS, investigations have been completed for the District and recommendations submitted by the University of California, Citrus Experimental Station, located at Riverside, California, as to the type and use of insecticide for the control of Chironomidae and mosquitoes; and

WHEREAS, these insecticides are generally of the type classified as organic phosphates, some of which are toxic to humans if not utilized and applied in the proper manner; and

WHEREAS, Mosquito Abatement has developed the experience, methods, and necessary equipment for the application of such insecticides in conjunction with its delegated responsibilities of mosquito control; and

WHEREAS, District's Rio Hondo and San Gabriel River spreading facilities and related conveyance systems lie within or adjacent to the area served by Mosquito Abatement; and

WHEREAS, District desires to have the ability to request treatment of spreading areas with insecticides on an intermittent basis and when other control measures other than insecticides are not satisfactory; and

WHEREAS, Mosquito Abatement is prepared to undertake a program of insecticide application to areas owned and operated by the District and as provided in this agreement; and

WHEREAS, it has been concluded that the cost for such a program of an intermittent nature can best be evaluated in terms of materials, labor, and equipment on an hourly basis; and

WHEREAS, Mosquito Abatement will incur certain routine medical expenses required when using organic phosphate insecticides for which reimbursement should be made.

NOW, THEREFORE, in consideration of the foregoing and the mutual covenants hereinafter contained, it is hereby agreed by and between the parties hereto, as follows:

1. Mosquito Abatement agrees to apply parathion or other insecticides, upon telephonic request by District to the Manager of Mosquito Abatement, for the control of midges and/or mosquitoes infesting Water Conservation facilities of District within and adjacent to the Montebello Forebay. Such request to be concurrently confirmed by letter from District to Mosquito Abatement.
2. Mosquito Abatement agrees to supply all materials, labor, and equipment required for applying such insecticides.
3. Mosquito Abatement agrees to obtain the necessary permit or permits from the County Agricultural Commissioner's Office for the use of parathion and any other organic phosphate insecticides utilized for said insect control which are specified by the Agricultural Commissioner's Office.
4. District agrees to provide the necessary equipment for transporting the application equipment on and about District spreading and conveyance facilities.
5. District agrees to pay the cost of the application upon monthly billings in triplicate, by Mosquito Abatement not to exceed $5,000 per year. This cost to include:
   a. Hourly labor charges paid by Mosquito Abatement to employees properly chargeable to the agreed application operation, to include normal overhead of Mosquito Abatement;
   b. The cost of insecticides per pound or liquid measure, not to exceed the cost paid by Mosquito Abatement;
   c. Cost of equipment at 20 cents per mile; and
   d. Cost of intermittent medical examinations required for employees of Mosquito Abatement when in contact with organic phosphate insecticides resulting from applications at District facilities.
6. District agrees to reimburse Mosquito Abatement for all expenditures and commitments made by Mosquito Abatement pursuant to the provisions of Paragraph V of the above, not already reimbursed, if contract is terminated by either party as provided in this agreement.
7. District, to the extent which is authorized by law, hereby agrees to indemnify and save harmless Mosquito

Abatement, its officers, employees, agents, and representatives from and against all claims, demands, damages, costs, and liabilities resulting or claimed to result from any action or inaction of District pertaining to the performance of its obligations under this agreement.

8. Mosquito Abatement, to the extent which is authorized by law, agrees to indemnify and save harmless District, its officers, employees, agents, and representatives from and against all claims, demands, damages, costs, and liabilities resulting or claimed to result from any action or inaction of Mosquito Abatement pertaining to the performance of its obligation under this agreement.

9. It is mutually agreed, that this agreement shall remain in affect from the date of execution through June 30, 1963 and may be extended yearly upon the mutual consent of the parties hereto.

10. It is mutually agreed contract may be terminated by either party hereto upon thirty (30) days' written notice given to the other.

IN WITNESS WHEREOF, the parties hereto have caused this Agreement to be executed by their duly authorized representatives on the day and year first above written.

gnats). This contractual arrangement came about because our District had the technical ability, trained inspector-operators, professional and entomological support, as well as first-class equipment, all under competent supervision.

I have here (A) a request for service, (B) a sample contract, and (C) a survey form used in the interplay of work performance. To date, the contractual arrangements have been mutually satisfactory with a minimum of problems.

Arrangements with Department of Army, Los Angeles District Corps of Engineers, are handled by purchase order. Each Corps of Engineers' control operation is carried out in accordance with specifications on a purchase order, separate for each control operation.

Department of Water and Power, City of Los Angeles arrangements are performed by purchase order. This purchase order is prepared on a yearly basis so each control operation is billed on the same purchase specifications.

Data for each control operation is shown on SEMAD Form No. 33 (condensed for publication purposes). Materials and equipment expense is billed at actual cost as is personnel time. Personnel time includes overhead and all costs are figured on an hourly rate. These costs include all fringe benefits.

– SAMPLE –

C. – Survey Form

ENTOMOLOGICAL SURVEY AND TREATMENT REPORT

Type of Service Performed: . . . .

Date: . . . .

Pest Species: . . . .

Agency Requesting Service: . . . .

Location: . . . .

Material Used: . . . .

Acreage: . . . .

Dosage Rate: . . . .

Total Amount: . . . .

Personnel Time: . . . .

Equipment: . . . .

Remarks: . . . .

SEMAD Form No. 33
1–13–69 50

DISTRICT ACTIVITIES AND RELATIONSHIP TO VARIOUS JURISDICTIONS

Howard R. Greenfield
Northern Salinas Valley Mosquito Abatement District, Salinas

When approached by Mr. Brumbaugh to be a member of the Interagency Cooperation Panel, I accepted, believing that it would be a simple matter to acknowledge how well interagency participation and cooperation works for those in mosquito control; and, in particular, how well it works in the Northern Salinas Valley. After critically reviewing our own District programs and the cooperative agreements related to these activities, it would perhaps be wiser to title this presentation, "The Myth of Cooperative Relationship with Various Jurisdictions."

Legally, any district is empowered to enter into cooperative agreements or contracts in the furtherance of the objectives set forth in Section 2270, Article 4, California State Health and Safety Code. Fortunately, no limitation is placed upon the degree or extent to which participation occurs in so-called cooperative agreements, and no limitations appear to be established regarding the activities a district may participate in, as long as the goals and objectives of the district are adhered to.

What are the goals and objectives of a mosquito abatement district? First, it must be remembered that a mosquito abatement district is essentially a specialized extension or arm of our public health programs. Its structure is both political and geographical, and it is charged with the responsibility of protecting the public well being by controlling mosquitoes, but it is not limited to just mosquitoes. It may control flies or other insects of public health concern if deemed necessary by the trustees of the district. It is these very powers granted by law to the trustees of every mosquito control district, coupled with the surging population growth in California (20 million now) that will propel and actually force mosquito control agencies into greater and greater participation with all political entities from the federal level to the special interests within each county.

Is mosquito control being forced in this direction now? Yes, I am certain that every district in the State of California is aware of these forces and is doing something about them. Not all districts are involved to the same degree or in the same problems, but they are involved and that is what matters.

Locally, our first involvement in problems of drainage systems was actually forced upon our then newly-created, ill-equipped, inadequately-staffed Mosquito Control District by the County Board of Supervisors and the City Council. This is how it happened.

In 1916, the agricultural interests conceived and gave life to a drainage and reclamation project known as District 1665. Its purpose was to develop, construct and maintain a system of drains that would protect the farm lands of the Salinas Valley from flood water damage and would re-claim large acreages of peat bottom land for intensive crop production. From 1916 to 1950, a period of 34 years, this drainage system served the agricultural interests. However, with the passage of time, commercial growth, industrial growth and community growth began to use this agricultural drainage system as a waste water system. By 1951, the combined industrial and community waste water usage far exceeded any use agriculture had for the drainage system. Thus, the directors of 1665 paid off the bonds and folded up the operation.

Now, such actions were totally disconcerting to the "City Fathers" and the governing Board of the County, because with no duly constituted legal authority, who would maintain this most important structure? After much discussion with the District Trustees, it was decided that maybe the Mosquito Abatement District should be the responsible agency, because after all, stagnant water, polluted water and highly charged organic waste water could breed hoards of mosquitoes. Thus, in 1952, our first interagency agreement was concluded, and for 17 years the Mosquito Abatement District provided a trouble-free, mosquito-free, fully functional drainage system for all interests – community, agricultural and industrial. I must add that this one cooperative agreement has led or forced us to participate in many other agreements some of which I will mention briefly:

1. Weed Control
2. Drainage Construction and Maintenance
3. Soil Conservation Service Districts
4. Industrial and Community Waste Disposal Systems
5. Recreation Planning
6. Flood Control and Water Conservation
7. Training Programs (for the health department as well as in-service training).
8. Watershed Protection & Flood Control Structures

In summarizing what has been presented, I must state that the role played by vector and mosquito control districts is unique. Unique because the vectors we strive to control recognize no political subdivision or jurisdiction. It is because of the mosquitoes and other vectors of public health interest that we seek interagency understanding and cooperation. Whether or not we play the dominant role or the subordinate role in these cooperative agreements is unimportant, as long as we achieve the goals set forth. And finally, the term cooperation – meaning working jointly together for a common goal – is still today a myth, but hopefully tomorrow an altruism.

AGENCY COOPERATION

George Umberger
Sacramento County – Yolo County Mosquito Abatement District, Sacramento

The Sacramento County–Yolo County Mosquito Abatement District has a cooperative agreement with the United States Bureau of Reclamations to do mosquito control work on the Bureau's property. The Bureau pays the District for this control work to a maximum of $1,500 per year. There are two installations on the east side, Folsom Dam creating Folsom Lake and Nimbus Dam creating Lake Natoma. On the west side on Putah creek is Monticello Dam and about 5 miles downstream is a diversion dam creating Lake Solano.

Soon after the construction of Folsom and Nimbus dams, limited mosquito breeding was noted on the edges of Lake Natoma. This lake is located in the dredger tailings and creates pot holes in which there can be rather serious mosquito breeding. This matter was reviewed with the Bureau and a program was evaluated whereby the Bureau would enter into a contract with the District, paying $4.15 per hour for mosquito control work done on its property, with a limit of $1,000 per year.

Upon completion of Monticello Dam and the diversion dam on the west side of the District, new mosquito problems were noted there. The contract covering mosquito control work was increased to $1,500 per year. An interesting factor in the mosquito control relationship is the review by the Bureau of Reclamations of the mosquito problem areas, with the intent to do corrective measures to eliminate mosquito breeding if the corrective costs will not exceed a 5-year control cost. The water from both of these Bureau installations is used for drinking purposes, and corrective measures are desirable to eliminate the need for chemical control work.

COOPERATIVE SOURCE REDUCTION IN THE EAST SIDE MOSQUITO ABATEMENT DISTRICT

Gordon F. Smith
East Side Mosquito Abatement District, Modesto

The term "source reduction" is something like "motherhood" or, more recently, "ecology" or "pollution". Too often it is used loosely without relating it to the specific problems involved, and yet it is recognized that problems vary widely from one mosquito abatement district to another.

The problem areas in the East Side Mosquito Abatement District lie partly in foothills and partly in flat lands and delta areas. They contain two large and one small irrigation districts and virtually all irrigation is done from canals with water available on a rotation basis – in the heat of the summer on a 7 to 10 day schedule. The flat lands, where our most difficult problem lies, are mostly in the Modesto Irrigation District, which is one of the oldest such districts in the state. Land was levelled here without regard to drainage and with much destruction or diminution of natural drainage-ways. The problem then was to get the water on the land, not to get it off.

Much of the land is over shallow hard-pan which supports a perched water table during the irrigation season and which effectively prevents percolation. The western portion is very flat with little effective grade for drainage. A major portion of the District is in pasture because the soil types will not support a higher income crop. Unfortunately pasture is not often treated as a crop or, as I told one dairyman, his wife took better care of the front yard. Water in the District is either free in the Modesto Irrigation District or at very low cost in the other two irrigation districts. Because of this and the ready availability of water, there is little incentive for on-field drainage such as tail water return systems.

What the area needs is a master drainage plan with trunks and laterals. A drainage committee has recommended preliminary engineering studies, but finances have not been made available. This being the case, most drainage must go into irrigation canals, since, due to the canal system, rivers are not readily available to the land. The whole problem tends to require area drainage rather than working with individual ownerships. There is, within the irrigation district laws, provision for forming special assessment areas or districts for local improvements such as irrigation distribution and drainage systems, and this is the procedure of choice. A petition is required, signed by over 50% of the property owners and representing over 50% of the land area.

There are several other agencies interested in drainage besides the East Side Mosquito Abatement District. Basically these include the County Department of Public Works, Irrigation Districts, Agricultural Extension Service, and the Agricultural Conservation Service. Others, such as the County Health Department, Water Quality Control Officials and city officials have interest in some cases. We have tried to develop a close relationship with all of these agencies to see that in any proposed project the needs of all can be met and that all who can contribute financially or otherwise are in the picture.

Area drainage takes a lot of leg work, not only in contacting and working with other interested agencies but in contacting the individual property owners and gaining their cooperation. It is in this area of leg work and coordination that the District seems to fit the picture best.

PANEL: LEGISLATIVE ACTIVITIES

Senator Lewis Sherman, Alameda County

It is critically important in the legislative process that a bill get through a committee. The bill may go on to an additional committee in the same house where it may meet the same requirements. Then it must pass the floor of that house. Then it must go over to the other house and go through the same process. Therefore, you should determine the committee to which a bill in which you are interested is assigned, then concentrate on the persons on that committee first.

When you write to your legislators, it is critically important for you to give reasons for your position. Each of us legislators can take such a letter to that committee hearing, and when the people before us are testifying, we can use those reasons or those questions to test the validity of the testimony before us. Do not get trapped into a situation of mass mimeographed letter writing. This does us no good – it does not represent original thinking. We prefer a letter which may have misspelled words or poor English but which does raise a critical or important point.

Senator Joseph Kennick, Los Angeles County

Letter writing is a splendid form of communication with your legislator, particularly if the letter is well thought out. Do not just make a statement, but give a reason, arriving at a logical conclusion as to why a measure should be passed or defeated. But do not write too long a letter. There is not a legislator in state government who will not read your letter and who will not act upon it, one way or another.

So many legislators assume that when someone comes to see them he wants something, or he is in trouble. But you should come in to see your legislator even if it is just to get acquainted with him. Such a visit can make a good impression so that, if you should write him at a later date, you and your legislator will be better acquainted and will have a better understanding of each other. We legislators are engaged daily with the most intricate of legislation. Not a single one of us concerned with the truth would lead you to believe for a single moment that we know the answers to all the problems with which we are confronted. But we know where to go to find the answers – various citizens who are authorities in various fields.

Assemblyman Don Mulford, Alameda County

I would like to tell you what I believe to be the most direct way to become acquainted with Sacramento. Having served 10 years on the Public Health Committee during the 12 years of my service as an Assemblyman, I have some understanding of the problems, the public relations and the science involved in your work, yet I happen to believe that your work is not recognized by too many people, both in your communities and in the Legislature. I think that you have a selling job to do for support! Has your Association obtained a yes vote and a passage of all of your bills? If it has not, then I would suggest that a successfully conducted and mounted political operation usually is able to come out with close to a 100% batting average.

There are 5 to 6000 legislative matters to handle each year. You, as a special interest group, want to know "How do we get our legislation through successfully?" To me, the most sensitive time of the year is campaign time. We need help, money, people – all of these tools to get elected. It is during this sensitive period that we legislators are most receptive to your wishes. It is the time we are most anxious to become acquainted. You must get on a first-name basis with your state and federal legislators. In such areas as yours, where we are operating in the public arena, there is no room for partisanship. In fact, about 90% of the work we do is nonpartisan in nature.

To me, the most important way to become an effective personality in the legislative scene is to be on a strong, first-name basis with your legislators.

Assemblyman Ernest Mobley, Fresno County

Your Association does write letters, because I have received some from you. One important thing is timing. At the last session I counted up to 15 different times when I received important telegrams and communications from organizations and individuals, but I received them after the issues had left the Assembly – too late for action.

Be careful when sending telegrams – many times these are not clear.

Another thing is the "Resolution". This type of action is passed by many organizations, often going to the extremes in wording. My advice is: Do not spend the time that apparently has been spent on resolutions. Naturally, they do present your point of view. Resolutions are usually duplicated, sometimes with a nice seal at the bottom, but they do not really give us the reasons we need in order to help us make our decisions. I would say that a good, well written letter by the secretary of the organization, rather than a resolution, would be more effective with me.

Another important thing: if you are making a communication from the official body, such as a district or association, make certain that the letter states that it is the official position of the organization. Many times we get a letter from an individual of an organization, and we may take for granted that he is representing the whole organization, when in fact he may be stating a minority view – make certain your majority view is stated in your communication.

The personal contact has real effect. If I can pick up a phone and call you and ask you about something on which you are informed, and you can brief me to tell me how you feel about it, and how it may affect your organization, this will be a help to both of us.

INTRODUCTION TO PANEL: A REVIEW OF *GAMBUSIA* EFFECTIVENESS

Jack Fowler
Sacramento County – Yolo County Mosquito Abatement District, Sacramento

Not all activity in the early West was gun slinging, cattle rustling and digging for gold. The naturalist also was at work. Baird and Girard described the *Gambusia* mosquito fish in 1853 from specimens taken at the Rio Medina and Rio Salado, part of the San Antonio River drainage in Texas. Beginning in 1904 the first major account of *Gambusia* in the United States was credited to W. P. Seal in New Jersey. Alvin Seale, under the direction of David Starr Jordan introduced *Gambusia* to Hawaii in 1905. From Hawaii fish were taken to Formosa, the Philippine Islands, Singapore, Mandalay, Bangkok, Japan, and China. The U.S. Bureau of Fisheries in 1919 took an active interest in the *Gambusia*, and a year later was asked to send specimens into Italy and Spain. Distribution was extended soon after to all Southern European countries as well as Germany and Austria. Mosquito fish from Spain were also taken to Russia, the Island of Cypress and then to the Union of South Africa. In 1922 *Gambusia* were introduced into California from Texas with the initial planting in the pond at Sutter's Fort. Distribution in what is now the Sacramento County–Yolo County Mosquito Abatement District was undertaken in 1940 by Hugh Hart, who will be speaking later on this program. In 1941 the Malaria Institute of India recorded its experience utilizing fish in India's malaria control program. In 1943 the first published work appeared in Mosquito News, observations by J. L. Clark.

Gambusia rightly or wrongly have been credited as valuable control in many malaria and yellow fever areas in the world. Some authors give *Gambusia* credit for controlling yellow fever, thereby allowing the Panama Canal to be built.

In reviewing the history of *Gambusia* one runs across accounts (e.g., Myers 1965) of the disadvantages of their use for mosquito control, for instance, accounts of the destruction of young bass at Friant 35 years ago and claims of a heavy toll of the young of important food or game fishes elsewhere. In the canals of Bangkok, Thailand the native larvivor is now rare and another indigenous fish has disappeared. In the creeks around Laguna de Bay in the Philippines native fish are said to be gone and *Gambusia* reigns. Similar results from the introduction of *Gambusia* are reported from the lower Nile River and in garden ponds in California where allegedly *Gambusia* are holding the goldfish population down. How ominous are these reports? Can this be likened to the introduction of rabbits into Australia?

An outstanding bibliography on *Gambusia* was written by Gerberich in 1946. Under the auspices of the World Health Organization in 1966 and United Nations Food and Agriculture Organization in 1968 this bibliography has been revised and enlarged (Gerberich and Laird 1968). Much interest in the use of *Gambusia* as a naturalistic control measure occurred from the turn of the century until about 1930. Very little is recorded subsequent to this until the early 1950's. Today, in response to problems posed by both resistance and long lasting deleterious effects of certain insecticides, there is a marked trend back toward greater use of *Gambusia*. Present day workers attempt well conceived programs, but I'm afraid some of us fall short of the detailed attention required for successful mosquito fish husbandry, resulting in questionable or negative results. The reports you will hear in the panel to be presented now should illustrate something of the importance of detail in this approach to mosquito control.

References Cited

Myers, George S. 1965. *Gambusia*, the fish destroyer. Trop. Fish Hobbyist. January.

Gerberich, John B., and Marshall Laird. 1968. Bibliography of papers relating to the control of mosquitoes by the use of fish – An annotated bibliography for the years 1901-1966. FAO Fisheries Tech. Paper No. 75. Food and Agriculture Organization of the United Nations. Rome, Italy. 70 p.

MOSQUITO FISH IN YOLO COUNTY

Hugh G. Hart
Sacramento County – Yolo County Mosquito Abatement District, Sacramento

My first introduction to the use of mosquito fish for mosquito control was in 1938 while taking graduate work in Public Health at the University of California at Berkeley. One of our field trips was to the Alameda County Mosquito Abatement District, and some of their mosquito abatement procedures included the use of *Gambusia*.

In returning to Yolo County and the numerous mosquitoes, initial surveys indicated many areas where it appeared that mosquito fish would be useful. There was no district and little or no funds. We came to a conclusion contrary to the textbooks of that day and that was that *Anopheles freeborni* traveled much farther than was supposed, in fact, a very considerable distance farther. We also learned that Solano County Mosquito Abatement District was using mosquito fish. They were contacted and graciously consented not only to furnish us with fish but also to help us plant them and we did plant them in every conceivable place. Some came to naught but many areas proved favorable and as a result, mosquito fish were in considerable evidence in Yolo County at the time of formation of the Sacramento County – Yolo County Mosquito Abatement District.

New types of sewage lagoons in the last ten years were pioneered in Yolo County after an extensive survey of lagoons in all parts of California and in a number of other states as well. Mosquito control was one of the anticipated problems and the use of mosquito fish was considered. A considerable amount of experimental work had been done on lagoons. Most of the lagoons had too little oxygen to support *Gambusia*. Lagoons are classified as aerobic if they contain oxygen and anaerobic if they do not. Lagoons must be aerobic if they are not to produce odors. Anaerobic lagoons are by far the more efficient of the two but must be used where odor is not objectionable. But the aerobic lagoons can still operate at a dissolved oxygen content less than 4 parts per million, and on a cold, foggy night the dissolved oxygen content may drop to almost zero.

Nevertheless, *Gambusia* were planted in all ponds and only survived in those where the loading was light so the oxygen content was not depressed. In many lagoon systems the use of secondary and tertiary lagoons is necessary and it is here that *Gambusia* thrive. There are abundant nutrients available for algae and aquatic life and Gambusia reproduce and develop in tremendous numbers in this environment.

It is our belief that the success of *Gambusia* is dependent upon an ample supply of these fish at the right time and sewage lagoons are the most likely place to produce this supply. We are developing more ponds for this purpose.

There are, nevertheless, some problems in this field and they are not all understood. One thing we do know is that water must "recover" in the secondary and tertiary lagoons before a satsifactory environment for mosquito fish is present.

The ponds may, in the future, be modified so as to make it easier to retrieve the fish when they are needed.

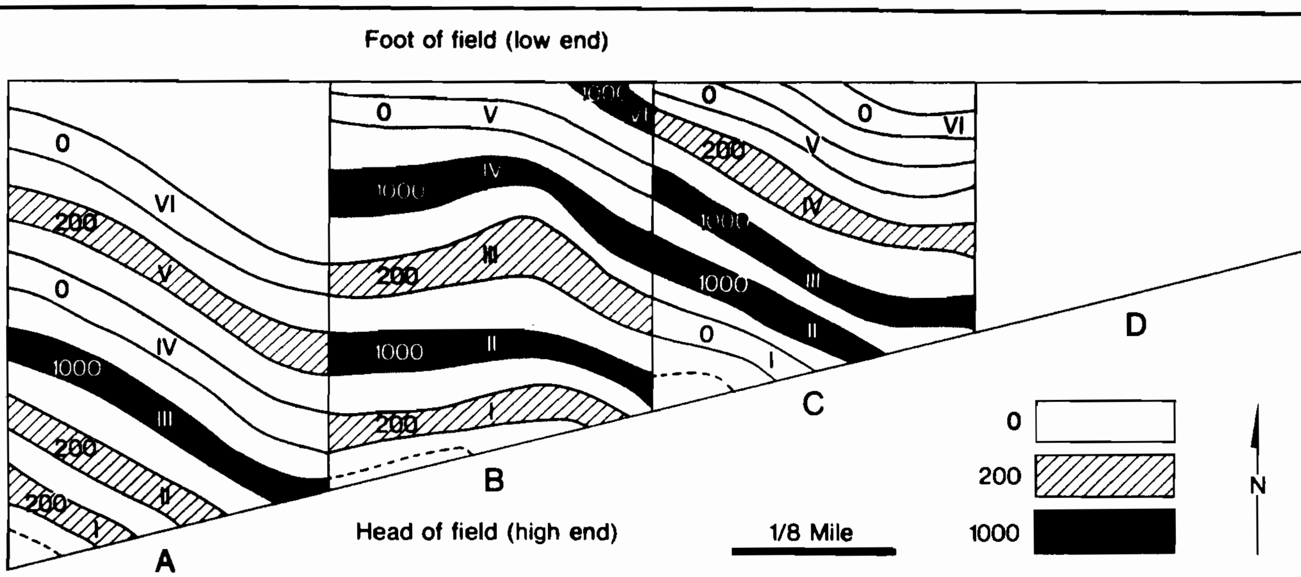
A RECENT TEST OF *GAMBUSIA* FOR MOSQUITO CONTROL IN A RICE FIELD

James B. Hoy
Entomology Research Division, USDA Fresno[1]

During the past four years I've been informally compiling a list of reasons that have been given to me to explain the limited use of *Gambusia* in rice fields, criticisms such as: (a) the fish avoid the vegetation; (b) the fish avoid the center of the paddy; (c) the fish stay near the irrigation boxes; (d) the fish stay in the warm water. Another type of reason is that there aren't enough fish for proper stocking. Also given are reasons such as: If fish are stocked they are killed by bluestone or draining of the field. Also the reliability of the method is questioned in general terms. And finally, I must mention specific criticism such as: *Culex* are controlled but not *Anopheles*. Another variation of this criticism is that *Anopheles* are controlled but not *Culex*. Despite the conviction in the voices of the critics, publication of data to support these criticisms is lacking. Logical examination suggests that regardless of where the fish are observed in the field, the question at hand is "What stocking rates are necessary to control mosquito production?" Beyond that, the economics of stocking (and restocking after bluestone treatment or draining) should determine whether or not *Gambusia* can be used effectively. A very important part of the economics is producing an adequate supply of fish.

The remainder of my talk will be a report of a field test of two stocking rates of *Gambusia affinis* (Baird and Girard) for mosquito control in rice. The details will be published

Figure 1. Map of the study area. Total area 145 acres, 35 of which were stocked with fish. The stocking rates and experimental control plots are indicated by 200, 1000, and 0.



[1]5544 Air Terminal Drive, Fresno, California 93727.

in Mosquito News as a part of the Proceedings of the 26th Annual Meeting of the American Mosquito Control Association (Hoy and Reed 1970).

A brief description of the study is as follows: David E. Reed, Manager-Entomologist of the Fresno Westside Mosquito Abatement District and I began the study in March of 1969. The experimental design was random assignment of three treatments (1000 fish/acre, 200 fish/acre and 0 fish/acre) to the paddies of a single rice field. Each treatment was replicated 6 times. Figure 1 shows the arrangement of the field with respect to stocking rates. The levee boxes were screened with both 4 and 8 mesh hardware cloth to prevent movement of the stocked fish, all of which were large mature females. The paddies were stocked in late May and evaluated for mosquito production five times at two week intervals, beginning 23 June. Evaluation by experimentally naive and experimentally sophisticated men gave very similar results. These comparisons were made during the first and third evaluations.

For the whole season 94% of the larvae and pupae [all were *Culex tarsalis* (Coquillett)] found were in the paddies where no fish were stocked, 5% were where the stocking rate was 200/acre, and 1% were where the stocking rate was 1000/acre.

From this study we concluded that *Gambusia* can be quite effective when stocked at 200/acre and a broad scale testing program is justified.

References Cited

Hoy, J.B. and D.E. Reed. 1970. Biological control of *Culex tarsalis* in a California rice field. Mosquito News 30(2):222-230.

ADDITIONAL NOTES ON *GAMBUSIA* HUSBANDRY IN THE SACRAMENTO COUNTY – YOLO COUNTY MOSQUITO ABATEMENT DISTRICT PROGRAM

Richard Russell
Sacramento County – Yolo County Mosquito Abatement District, Sacramento

Since the last conference that was held here in 1964, several improvements have been noted in our fish husbandry program. The most important aspect is the use of the series pond type of sewer lagoon system as a *Gambusia* fish rearing pond. We have two of these systems operating in Yolo County. One is located at Esparto which is about seven years old and is a five pond system with four ponds active. The other is located at Madison which is about three years old and is a three pond system with two ponds active. Both systems serve communities of 1500 or less.

Two thousand *Gambusia* fish were introduced into the final or 4th pond at Esparto about five years ago. The next year 300,000 fish were removed. The following years the number increased until 1968 when in excess of 1.5 million fish were removed. In 1968 fish were introduced into the third pond at the Esparto system. These fish multiplied and grew at an amazing rate with the result that over 3 million fish were harvested from both ponds in 1969. An inspection of the ponds in October of 1969 showed that the number of fish appeared to be at a level equal to that of May, 1969, or before any fish had been removed.

The ponds at Madison show as much promise as the Esparto ponds with the exception that Madison has only 200 + users, resulting in a lower rate of spill from pond to pond. Through the cooperation of the service district, fresh water was introduced into the system, maintaining a favorable level in the rearing pond (final pond). From 42,750 fish planted in the fall of 1968, 350,000 were removed in 1969. With the apparent growth and multiplication noted last fall we anticipate a harvest of more than one million fish in 1970.

Seining of the ponds is quite easy. Since the water can be regulated in the final ponds, the level is lowered to 2¼′ to 3′ deep during the fish harvest season enabling the crews to wade the entire pond. A 50′ to 75′ three-sixteenth seine is used and in a distance of 200′ we can usually catch from 80 to 120,000 fish per pass. Since the water level cannot be lowered in the third pond seining is done by using a rope on the seine. This method takes a little longer but the number of fish caught is about the same as the other method.

Two revisions are utilized in the transporting of the fish. The first is that 15-gallon garbage cans with lids are now used in place of the milk cans. This enables us to increase the capacity of fish from 6,000 to 10-15,000 fish per can. The second revision is the use of ice to cool the water. This method is used only when the fish are to be kept for an extended period of time in a crowded transporting container. Adequate aeration is still used at all times.

The use of our two-way radio system proved to be an invaluable tool for the transporting of fish. Due to a repeater station located on a mountain in western Yolo County complete radio coverage of our district is achieved. This allows us to direct the transporting trucks to planting areas and to call for assistance in the event of a breakdown with a minimal loss of time and fish.

Pond maintenance is still carried out although on a smaller scale. In the case of the lagoon ponds most maintenance is done by the service district. However, our District cooperates by doing limited chemical control of weeds around the ponds that we use. Also our mechanic built a weed cutter that is used to cut pondweeds in the seining areas. This light weight piece of equipment has proven very successful in our operation.

Soil sterilant was used around all the gates, parking areas and trail areas in and near the mountain reservoirs that we use in rearing ponds. This practice reduces the hazard of fire and of course, that of rattlesnakes which are ever present around the reservoirs.

EQUIPMENT DEVELOPMENT FOR WET–LAND MOSQUITO CONTROL

Karl L. Josephson
Box Elder County Mosquito and Fly Abatement District
Brigham City, Utah

The Box Elder County Mosquito and Fly Abatement District consists of the perimeter of Box Elder County and contains 5600 square miles with an assessed valuation of $64 million. At a maximum taxing ability of one mill levy it is impossible to receive enough money to control an area of this size. We are only attempting to control mosquitoes in the more populated areas – this covering approximately 2500 square miles.

In our District we have the largest federal game bird reserve in the world. We have two-thirds of Great Salt Lake, two rivers, each running 50 miles through our District, the largest area of irrigated farms in the state and 40 or 50 private duck clubs.

We have many vast submarginal areas of natural wild grass pasture surrounding the lake and river areas and this problem prompted our development of a vehicle that could make ditches to control the water in these areas.

In the fall of 1963 I talked with my son Paul, who worked with Thiokol, Logan Division, as a designer of off hi-way snow vehicles. We talked of a tractor that might pull a plow or ditcher in our soft, muddy, submarginal areas. He told me the Spryte should do the job. We arranged for a demonstration. The date was set and I borrowed a new International ditcher from Brigham Implement. This ditcher didn't have a hydraulic ram on it and was adjusted only by hand crank. We towed the ditcher to the field by Jeep and met Paul with the Spryte there. We had some board members present and some of our employees there also. The field was north of Brigham, part of a large meadow area that is always too wet to farm. We decided to follow an old drain that was filled from years of "tromping" by cattle and other livestock. The ground in this area oozed water as you walked on it and had a fair sod of salt grass, etc. We started out and what a surprise! We made a ditch, a beautiful ditch 18″ deep and 36″ wide. As we proceeded at about 5 mph, the ditcher went deeper and deeper and stopped the Spryte. We backed the Spryte and ditcher out, readjusted the ditcher and went on. We soon got into standing water a foot deep on top of the ground! We still went on making the ditch to the place where we wanted to stop. This was more than a half mile of ditch in less than an hour, and in an area that, as one board member put it, "would mire a saddle blanket". What a thrill, I had put something together that would do much good in areas that were so neglected.

During 1964 we made a survey of all submarginal areas by taking a cross section of property needing service. We then made maps of these areas, figured approximate lengths and depths of ditches needed and contacted a local contractor to get his price to dig these drains. The least expensive bid, using a backhoe was $20,000.

To the property owners surveyed, we sent a letter explaining the object of the survey and a questionnaire to be answered and returned in a self-addressed, postage-paid envelope. On this we asked, "Would they consider paying all, part, or none of the cost for the drains we suggested". More than half of the returned sheets said they would bear part of the cost and only three said "no drain construction".

This information was presented to the Board during the winter 1964-65 and after much consideration and discussion, I was directed to purchase the equipment to start a "water management program". Meantime, I had met with Blaine Rich, head of Thiokol, Logan Division. We discussed our problem and he came up with a Spryte they had taken in on a trade for a larger type snow vehicle from Mountain Fuel Supply. This unit had 27 hours use on it. We purchased it with a low gear for $5,617, a new International ditcher for $398 with a hydraulic ram attached to raise and lower the ditcher with controls in the cab of the Spryte and a trailer to haul the Spryte for one hundred and fifty dollars. The total cost was $6,165.

We felt that we could construct the drains for $10 per hour, paying all costs including labor for contacting property owners, for water control, for actual field work and prorating the equipment cost over a ten-year period. After our first year we raised this to $15 per hour with the property owners paying half the cost and our District paying the other half.

In most areas we can average a mile of ditch per hour. Some areas are slower because of excessive wetness or the type of plant growths they support. In wet or damp sod we

Figure I. Spryte and ditcher.

do well but in tules and bayonet grass in extremely wet land our operations are slowed. We very seldom find land that is too wet but have done so in a few cases.

So far we have been kept busy taking care of service requests. Neighbors adjacent to areas where we have provided service want the same service performed for them while we are there. As requests come in each owner is approached, his land checked and mapped and proposed ditch locations agreed upon by him and our District representative. Papers are signed by the owner, one guaranteeing payment of his share of the costs, and one releasing us from damages that might result from our work.

We mounted a spray boom and sprayer on the rear of the Spryte and powered it with a small Briggs & Stratton engine. The boom is a fold-away type and we found we can spray up to ½ acre per minute with this equipment. It covers a fifty-foot swath and we use this in areas up to fifty acres in size that can't be sprayed by jeep. We also have a hand nozzle and hose we use for spot spraying.

The success of this project is reflected in the reduction of sources of mosquito breeding areas, as well as better farming methods. We have seen pastures that had too much water on part and none on the other part raise a poor crop of "meadow hay" on part of it. After this was ditched, the "too wet" area and the "too dry" area all raised a good crop of hay by water management. We have seen wet areas dried up so a larger, more permanent drain could be dug by a backhoe. We have seen areas drain after flooding whether caused by rain or overirrigation.

We are not giving competition to any contractor as none of them have equipment to go into these wet submarginal areas and make ditches.

In 1969 we purchased a Vicon Fertilizer spreader and mounted it on the rear of our Spryte. This is proving very successful in spreading granular insecticide. It makes a good even spread and is accurate in the amount of application per acre. We can apply from 5 to 2500 pounds per acre.

We have had to make some changes on our Spryte during the process of making ditches; one of these being stronger belts for the track, another, replacing the rear 1500 pound axle with a new 3000 pound axle. We have put 1600 x 16 tires on the ditcher, which gives us much better control and made other minor changes. Thiokol worked with us on this all the way, giving us very fine backing and cooperation. They also made movies of several of our operations to use in selling their equipment.

INJECTION OF DURSBAN SPRAY EMULSION AT HALF MILE INTERVALS CONTROLS MOSQUITOES & CHIRONOMID LARVAE IN LARGE DRAINAGE CHANNELS

Albert H. Thompson, Curtis L. Barnes, and Douglas A. Mathews
Orange County Mosquito Abatement District, Santa Ana

It has been the goal of the Orange County Mosquito Abatement District to keep improving the control of mosquitoes and Chironomid midges in flood channels. A few years ago, when control of these channels started, the only known way at that time was the use of liquid larvicides. Due to the width of these channels, a two-man operation, one spraying and one driving, was necessary. A high pressure spray rig, mounted on a ¾ ton truck with four wheel drive was required. Channels with bottoms wider than 40 ft (our widest channel is 300 ft) required one operator to spray while walking the bottom edge of the channel. Another way was to spray from both sides of the service road. All of this took a lot of time, especially when material ran out. The operator would have to leave the channel to find a source of water before he could mix a new tank full of spray.

After a few years of treating flood channels using this method, the District switched over to the use of granule insecticides. International Harvester Scouts, a Thiokol Swamp Spryte and an air boat equipped with compressed air spray units, using the Orange County Compressed Air Granule Gun, were used for applying the granules. This method of treating channels proved to be much faster and saved time because the operator could carry enough granules to carry him through the day without stopping.

Orange County has been confronted in the past several years with an ever-increasing midge problem. In some locations, we have found that the Chironomid midges are a greater nuisance than mosquitoes especially in the past two or three years due to the great influx of population. We have found this problem to be acute near our flood channels and large rain-filled depressions throughout the lower elevation and the coastal area of Orange County. Farm lands which previously had produced dry lima beans and tomatoes have been replaced with homes located next to these breeding sources.

Street runoff water from the residential and commercial areas finds its way to the network of drainage ditches and flood channels which service our urban area of some 320 sq miles with a population of over 1,000,000 people. The drainage water is high in nutrients and creates a very favorable environment for midge production throughout the year, except during out infrequent flood flows during our winter months of January, February and March. The volume of street runoff water is sufficient throughout the remaining nine months to maintain a constant flow to a depth of six inches to several feet in most channels. Midge larval populations will run from eight to 150 per sq ft of bottom mud. Mud samples are taken by a specially designed 4″ x 4″ nylon net. Larval counts are made in the field by using a grid-scaled pan. Duplicate mud samples taken by our vector ecologist using glycerine for separation of the very small midge larvae contain from 50 to over 800 midge larvae per sq ft. Using these actual figures for the 107 channels running 250 miles in length, one can readily estimate the tremendous numbers of adult midges which can be produced by these channels.

During the 1968 season, both Baytex® and Abate® gran-

Table 1. Toxicant injection time for control of Chironomid larvae and mosquitoes in drainage channels.

	For Equivalent Dosage Rate		of	0.05 lbs toxicant/acre			
	Or " " "		of	0.018 ppm for 12" depth			
	Using Standard Spray Emulsion		of	0.05 lbs toxicant/gallon			
	At Discharge Rate		of	0.2 gallons/minute			
			and	0.5 gallons/minute			
Area Below Inj. Point	Toxicant Required	Spray Required	Spray Time Required				
			0.2 gal/min		0.5 gal/min		
Acres	Pounds	Gallons	Min	Sec	Min	Sec	
0.1	0.005	0.1	0	30	0	12	
0.2	0.010	0.2	1	0	0	24	
0.3	0.015	0.3	1	30	0	36	
0.4	0.020	0.4	2	0	0	48	
0.5	0.025	0.5	2	30	1	0	
0.6	0.030	0.6	3	0	1	12	
0.7	0.035	0.7	3	30	1	24	
0.8	0.040	0.8	4	0	1	36	
0.9	0.045	0.9	4	30	1	48	
1.0	0.05	1.0	5	0	2	0	
2.0	0.10	2.0	10	0	4	0	
3.0	0.15	3.0	15	0	6	0	
4.0	0.20	4.0	20	0	8	0	
5.0	0.25	5.0	25	0	10	0	
6.0	0.30	6.0	30	0	12	0	
7.0	0.35	7.0	35	0	14	0	
8.0	0.40	8.0	40	0	16	0	
9.0	0.45	9.0	45	0	18	0	
10.0	0.50	10.0	50	0	20	0	

ules were used with reasonable success for *Chironomus* sp. midges but with very little success on *Tanypus* sp midges. Excellent conditions for the production of midges occurred in 1969 immediately following the winter floods. During March and April 20 to 56 service requests were received per day. With the midges being a mosquito-like insect, the mosquito control operator's hardest job was to convince the requester that the midges were not mosquitoes and could not bite. True, the midge is a non-biting insect but the physical annoyance and mental agony it afflicts on the resident can be greater than dozens of mosquitoes. Homes located within a quarter mile of the breeding sources had thousands of midges resting on the outside walls, under the eaves and in doorways. They entered the home through the slightest crack in the door or open window, especially at night since they are attracted to artificial light. Throughout this period when hordes of midges were invading residential areas, our District was able to maintain and actually improve public relations only because our mosquito control operators had the training and the patience to explain the problem to each requester and to advise on what the District was doing to help alleviate the nuisance.

In April, we first experimented with Dursban® (4 lb. emulsifiable concentrate) by treating a flood channel at the rate of 0.05 lb per acre using the injection method. A four-hour re-inspection showed such phenomenal results that pictures were taken to show the masses of red *Chironomus* sp larvae that came up from the bottom mud to float downstream. From this point, we set plans in motion for power injection with Dursban at half-mile intervals at periods of 7 to 10 days. After two months of repetitive treatments, midge populations were reduced 60 to 70%. We feel these results were so outstanding we are now laying plans to expand this program throughout the District in 1970.

In the tests that were made during the summer of 1969, Dursban was used to make a standard spray solution containing 0.05 lb per gallon. This spray solution was applied at 40 pounds pressure using a Spraying Systems No. 22 Gun Jet with a solid stream nozzle No. 0002 discharging at the rate of 0.2 gpm. The channels were measured for total length and width to figure total acreage of breeding source area. A work sheet is made up on each channel giving the acreage between street crossing bridges and the number of minutes and seconds to inject the spray solution at each bridge. The injection time required per acre is shown in Table 1. One gallon of emulsion spray is required to treat one acre at 0.05 lb. The treatment time would be five minutes with the No. 0002 nozzle. Using a stopwatch, we inject the amount of emulsion needed corresponding to the amount of acreage in that half-mile section.

To sample the channels, three test stations over a one-half mile section were staked with markers in order to insure reasonable accuracy of location. One of the test stations was just below the injection point to get a sampling of maximum kill. A second station at the middle of the half-mile section, and a third at the end to determine the kill rate. Two mud samples were taken from each station and the average midge larval count recorded. Before the channel was injected, a pre-treatment count was recorded for each of the stations. Three days after the injection a post-treatment midge larval count was recorded. The percent of kill at each station and an overall percentage kill for the entire channel was figured.

Midge larval samples taken early in the summer of 1969 showed an average 75%-100% kill on *Chironomus* sp after the first injection. No re-occurrence of *Chironomus* sp larvae was observed for the rest of the season. The *Tanypus* sp midge larvae were not effectively controlled during the early part of the summer by this treatment. As continuous injections were made every ten days, however, control increased from 10% to an average kill of 65% by the end of June. This average percent kill remained about the same through the remainder of the summer and proved to be adequate to relieve the homeowners of the gross nuisance from adult midges. Later, we extended our injection cycle to 14 days with good success. We are considering lengthening our cycle to three weeks during the 1970 season.

It has been our experience during the 1969 season that the use of Dursban at a dosage rate of 0.05 lb per acre applied every 14 days to flood channels by our injection method at one-half mile intervals has adequately controlled both *Chironomus* sp and *Tanypus* sp midge larvae. Since this injection method requires only one spray operator, the man hours required to control our 250 miles of flood channels will be reduced by approximately 50% as compared to our previous area spray method requiring two spray operators.

IN–SERVICE TRAINING – SAFETY PROCEDURES

E. L. Geveshausen, Superintendent
Southeast Mosquito Abatement District, South Gate

Does your district have a safety program? Does your district have an "In-Service Training Program on Safety Procedures"? Does your district have a continuous monitoring program of the safety practices of the individual employee?

Many districts have safety programs and make these programs a key point in the training of the new employee. Too often though this is not a continuing program for the employee who has been employed for 5, 10, or 15 or more years. "Train them once and forget it" is too often the philosophy in many organizations. The realization of the importance of safety in all aspects of the operations of a mosquito abatement district must be renewed on a regular basis. The program should admonish the individual that safety is a way of life, his life and those around him. Point out to each individual that he not only should practice safety, but he should be aware of how those around him practice safety. There are attorneys around who make a very fine living by getting hold of individuals who have been injured, poisoned, burned or have developed psychological problems, real or imagined. Court cases have been lost because the employer could not prove that the employee had received instructions on the proper handling of materials or equipment. With the lack of proof the employee can claim negligence on the part of the employer, and collect damages. This can, and has happened even though the cases were completely covered by insurance.

You have a safety training program and it is being taught on a regular basis. Now comes the program within a program "monitoring". Who is going to monitor whom? If your program is properly oriented you are going to monitor yourself first. You ask, "Am I wearing the proper protective clothing when I handle any insecticides"? If you don't know, ask your supervisor. "Am I applying the insecticide in a manner that can be considered safe to myself, to the public, to domestic animals and to wildlife?" If you are not sure, again, ask your supervisor. "Do I wear the proper protective clothing such as rubber gloves, respirators?" "Do I wear adequate clothing to keep as much of my body unexposed as possible?" You have been instructed as to the proper procedures for the disposal of containers; are you following those procedures? You have now been monitoring yourself on the proper safety procedures in handling, applying and mixing of insecticides. You should now apply the same principles to the activities of your co-workers and, they to you. This is really the heart of the program, because unfortunately the old cliche, "Familiarity breeds contempt" is particularly true in the handling of insecticides.

The program I have outlined is equally effective for the safety procedures' program for shop practices and vehicle operations. This program can and should be implemented with occasional quizzes on the various safety procedures that have been imparted to the individual. Questions and suggestions should be encouraged to involve more totally each and every employee, including manager, technical staff, foremen, mechanics, operators, laborers and office personnel.

The Southeast Mosquito Abatement District's program on safety procedures consists of two formal instruction sessions during the year. The first session is conducted during the month of March for all permanent personnel. This session is particularly designed as a refresher course on all phases of safety. At this time the program is analyzed on the basis of the past year's safety performance record. Any suggestions for improvements or additions to the program are then called for. The second session is conducted when all of the summer employees have reported for work in June. This session is the most comprehensive of the two sessions and at the conclusion of the session, a quiz is given on the different phases of the program.

The safety training program is divided into three main categories: vehicle safety, insecticide handling, and shop practices.

The vehicle safety phase of the program is particularly concerned with preventive maintenance. A check list for the driver is a must. When you are looking for faults you should be aware that a small fault or deficiency can make your vehicle unsafe and a hazard to others on the street or highway. It is the driver's responsibility to spot the shortcomings and deficiencies. He is naturally more familiar with the vehicle than is the mechanic. If he can't handle the problem in his normal maintenance duties, he should tell the mechanic. We put particular emphasis on defensive driving techniques and observing all posted traffic regulations. There should never be any excuse for exceeding these limits. The safety equipment provided in each vehicle must be used with no exceptions.

That phase of our safety program concerned with insecticides begins with a study of the Cooperative Agreement with the California Department of Public Health relating to pesticide usage. A copy of this agreement is furnished to all employees and they are required to become familiar with it. A quiz is given to each employee regarding the allowable application rate of each pesticide used and of the different formulations, such as emulsions, granules, oils and combinations of oils and pesticides. We place particular emphasis on the need of each employee knowing what he is using, the amounts and methods of application for his safety and the safety of the public. Following this, is the observance of rules for cleanup, equipment and personnel, proper disposal of used containers and the Warning: Read and Understand all Precautions Listed on Labels. Believe What You Read On the Label.

Our shop-practices safety program stresses the use of safety equipment provided by the District when using equipment such as welders, drill presses, grinders. Be sure that proper signs, warning of the hazards involved when using such equipment, are posted nearby. All employees are cautioned never to use any equipment without training by qualified personnel. Each employee is again instructed to monitor his safety procedures and of those around him.

The safety program of any organization must be a continuous program throughout the year. There must be an awareness on the part of each employee that a successful safety program depends on the actions of each and every one until all safe practices are an ingrained habit.

A NARROW–SWATH AIRCRAFT SEEDER FOR GRANULAR APPLICATION

Loyd Messenger
San Joaquin Mosquito Abatement District, Stockton

The San Joaquin Mosquito Abatement District acquired its first aircraft for use at the start of the 1964 spraying season. Prior to this time the District contracted all aircraft spraying. As the amount of hours flown increased it became economical for the District to acquire its own plane and pilot.

During the 1964 season our aircraft treatment was limited to liquid applications. During this time we became aware of the need of an alternate method of treatment, as we quite often had need to treat an orchard with fruit being harvested, or near harvest, or to treat a source near bees or where bees were present or in those flooded areas with dense vegetation where five or even ten gallons per acre failed to control *Aedes vexans* populations.

Our first granule treatments were in 1965 with the standard Piper spreader and were very successful with the exception of *Aedes vexans* control in heavy wooded areas with extremely heavy underbrush. Control in these areas was later obtained by the use of malathion dust.

Because of the results with the large spreader and our unique situation in the San Joaquin Delta we started to think of a method of applying granules in a relatively narrow swath. In the Delta we have thousands of acres near or below sea level, which is crisscrossed with ditches for irrigation and drainage purposes. We have 1,800 miles of these ditches that are approximately four feet in width and 24 to 36 inches deep. They vary in length from less than 100 yards to 3/4 of a mile, with an average length of probably a little over a quarter of a mile. This is just to the west and northwest of the City of Stockton. Our prevailing winds are from the northwest (290°), so when these ditches become over-grown and choked with heavy weed growth they are a real problem as far as mosquito control is concerned. Species produced in the ditches are; *Culex peus*, *Culex pipiens* and *Culex tarsalis*, the encephalitis mosquito. Late in the year some *Anopheles* occur.

In most cases asparagus, tomatoes or some other edible crops are planted right up to the ditch, making it impossible to treat with a power unit. A man was able to treat only eight miles of ditches a day by hand, because of the time spent in getting to and from the work area, time spent in refilling the hand can or granule bag and because of the nature of the terrain. We are not able to use fish in these ditches because they are intermittently wet and dry. This led us to our experiments with the narrow-swath application of granules in the spring of 1966.

We first attempted a narrow swath by releasing a stream of granules out the center of the dump gate with no spreader. However, the propeller blast and other wind eddies generated by the aircraft structure itself made this method ineffective. Next we tried getting a narrow swath by putting granules only to the center of the standard Piper spreader.

We found we had granules distributed over the same range as if we had introduced them into each vane of the distributor.

I then designed a spreader with only one vane instead of the eight on the Piper unit. The Piper unit was used as a pattern for the general dimension around the hopper gate and a front opening of four times the size of the outlet was decided on, to try to over-come the propeller blast. The plans were submitted to a local sheet metal shop to have the unit built, but the price was estimated to be in excess of $300 for a unit that I wasn't sure would work satisfactorily, so I decided to build it myself in the District shop. Cost for material was approximately $25, and involved a period of two days' construction. It is built out of 20-gauge galvanized steel, as that material is easy to weld and is readily available. Weight is no problem as the unit hangs under the aircraft center of gravity and refueling is required before the entire contents of the hopper (800 lbs) can be distributed. Another reason that weight isn't too critical is that the general dimensions are such that drag produced isn't nearly that of the larger unit.

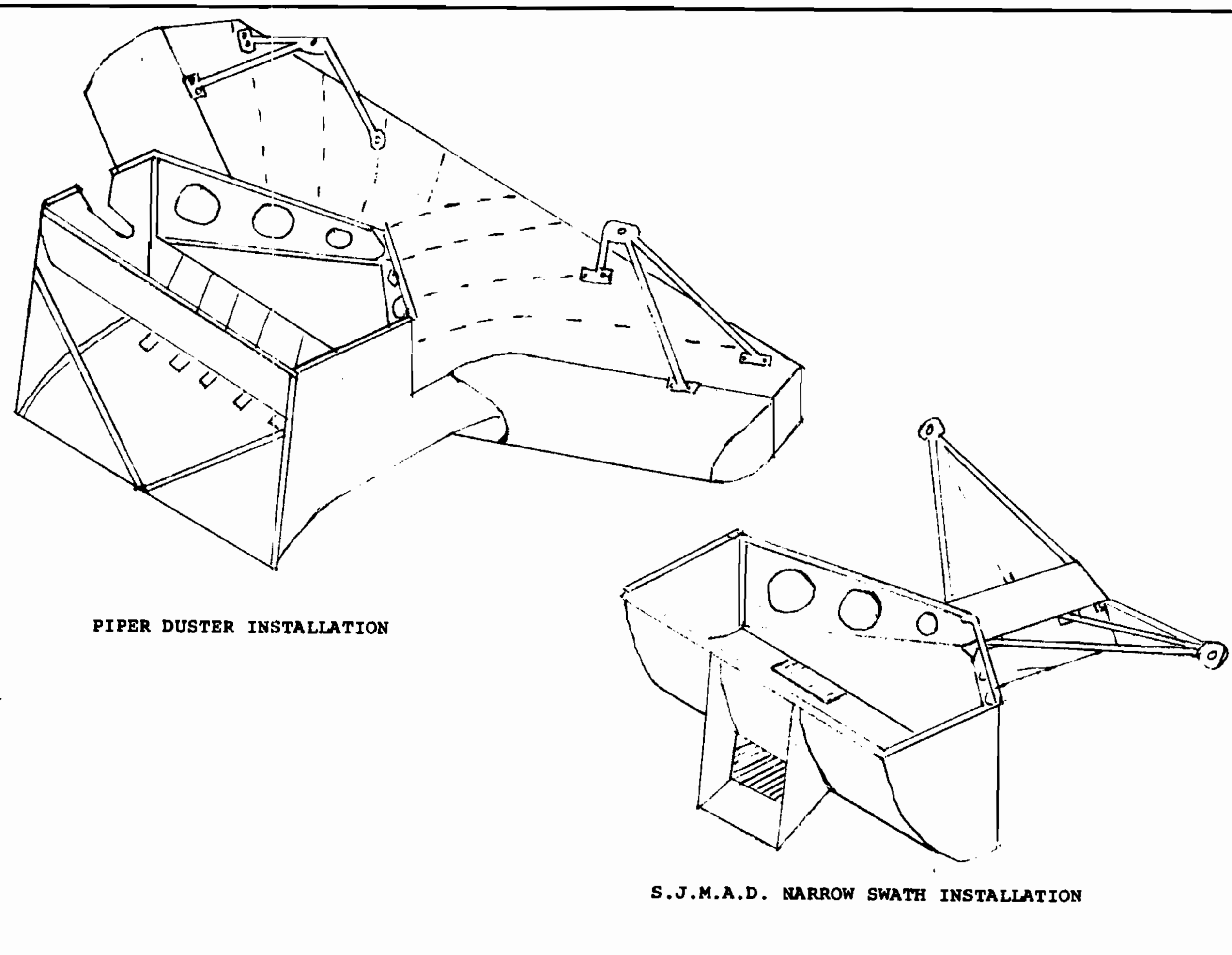
It is necessary to build a plate with an adjustable opening in its center to fit into the throat of the aircraft hopper to restrict granule flow to the small application rates desired, and to the center of the dump gate.

To calibrate the unit we put granules in the hopper and flew over one gallon cardboard tubs to determine our swath widths. Next we weighed specific amounts of granules into the hopper and flew a measured course, then landed, removed the spreader, dumped and weighed the granules left in the aircraft to determine the amount released. The size of the opening in the plate was then re-adjusted, the spreader put back on and the previous procedure repeated. After a number of flights we had the unit calibrated to five pounds per acre.

We use a 55 gallon chemical drum, split lengthwise with a T-handle attached to empty the aircraft hopper of the granules remaining in it. This unit has casters installed to make it easy to roll in and out from under the aircraft, as do both our large and small granule spreaders. We are covering an effective swath width of six feet in order to assure coverage of the ditches. It is necessary to limit flights to times of calm or light wind conditions, as the granules are quite easily displaced to the side by a cross wind.

We are using high release, 2% parathion granules of a 15 mesh size. It is most important that the granules be of an even size and be free of excess moisture to assure a uniform flow. Any lumps quickly plug the small opening. At five pounds per acre it is impossible to see anything flowing

Figure 1. Standard Piper applicator and San Joquin Mosquito Abatement District narrow-swath granule applicator.



from the spreader, and the granules go down so slowly in the hopper it may be some time before the pilot realizes he has a flow stoppage.

Acres granuled have been approximately 6% of our total acres treated, yet in man hours and aircraft flying time it amounts to approximately 30% of our total time. This is because of time spent in installing the granule dispenser, loading, ferrying to and from the job and the very narrow swath covered. We are able to treat about 50 acres per hour. We are treating less than one acre per mile of ditches flown.

Our chemical cost is about four times that of liquid, so one can readily see that this type of mosquito control is rather costly. In those areas where other methods aren't available and where nearby residential populations exist, the cost is more than justified. This is particularly true when *C. tarsalis*, the encephalitis mosquito, is being produced in the ditches.

One disadvantage is that granules aren't effective on the adult population or the pupal stage, so it is highly important to treat when the mosquito breeding is in an early stage of development. We were somewhat disappointed to learn that granules do not penetrate certain vegetation, such as heavy wooded areas or tall corn, etc., any better than do conventional emulsions.

Treatment of ditches with granules has been one of our standard treatment methods for the past four years. Taking everything into consideration, we are quite pleased with the results from the narrow-swath spreader and will continue to use it until such time as a more economical method of treatment is available.

We are doing some experimenting with the slugging or drip method of applying chemicals to ditches, but this must be somewhat limited as this water is pumped into the San Joaquin River.

SUPERVISION

Edward Leipelt
San Joaquin Mosquito Abatement District, Stockton

The job of a supervisor is to surround people with all those influences that will release their full potentialities. As a supervisor your effectiveness is measured by your ability to motivate people, obtain production within your unit. As a supervisor you are no longer judged on the basis of how much you can produce. Your job is planning, organization, leadership, controlling, evaluation, communications, public relations, discipline, absentee problems, but not to perform control operations.

In our Civil Service system we look for persons who have operational abilities, good judgement and individual output, and select these persons for supervisors. Most supervisors are promoted from the same work force they supervise. This new change of title puts you into what we refer to as the "vital shift". Formerly you were one of the boys; however, now you are a part of management. Your relationship has changed. You should attempt to establish friendly relationships with other supervisors as soon as possible. Exchange advice, information, personnel, equipment and assistance. But most of all, establish relationships with the work force. Here are some of the questions that the work force will ask; (1) will he use his authority, will he throw his weight around, will he play favorites; (2) what can he do for me? (3) what will his attitude be, will he be as friendly? (4) how will it be to work for him (will he be harder), how can I get around him?

It is your responsibility as a supervisor to make sure these questions are answered through your behavoir from the very moment you accept the position. You should always create a relaxed, free environment which will be open for discussion.

A vital function which you as a supervisor will encounter is volunteering factual and unbiased information to your supervisor about your unit's work. This information will assist him in better planning the Department's work. If you have any uncertainty as to what information your supervisor needs, answer the traditional questions of who? what? where? when? and how? If he wants more he will ask for it.

Make your information job related, avoid personal problems, private lives, choose subjects that are important to his work. Try to anticipate problems that are developing, needed equipment, hazards, weather, personnel, etc. Try to anticipate answers and questions your supervisor will be asking in order to achieve desired objectives.

Words are our primary means by which we communicate and most errors in communications are due to the kind of words we use. Be careful about using what we call "slippery words" and "slippery sentences". One word may mean many different things to different individuals. The word "run" has approximately 26 different meanings. I am going to read you several amusing examples of slippery sentence construction from welfare recipients: (1) "Mrs. Jones has not had any clothing for a year and has been visited regularly by the clergy," (2) "This is my eighth child. What are you going to do about it?" (3) "Please find out for certain if my husband is dead, as the man I am living with cannot eat or do anything until he knows:" (4) "I want my money as quick as I can get it. I have been in bed with a doctor for two weeks and he hasn't done me any good. If things don't improve, I will have to send for another doctor." I hope that some of these statements just mentioned will help clarify the meaning of a slippery sentence.

Leadership is rarely attained by individuals with the same combination of education and experience. The fact that a person is in a position of leadership does not mean he is an effective leader. We have formal and informal leadership. Most governmental organizations maintain formal leadership, with the chain of command and authority clearly defined, but informal leadership is present in most all organizations of any size. Many people understand the principles of good management and effective leadership and the appropriate ways of behaving toward other people, yet they do not carry out those principles. When thinking of self-improvement in dealing with others, remember that change can come only from within one's self.

People will strive to improve their status on the job if they feel they have value and are a part of the organization. If they have participation in decisions, deadlines, etc., they will subscribe to these standards without any major resistance. Authority, responsibility and delegation must be understood if you are to be an effective leader. Remember that although you have delegated a job to someone, that alone does not assure you that it will be done efficiently and you as a supervisor are still responsible regardless of the results.

There are many methods of communication. However, just to mention a few there are:

Oral	Written	
Staff meeting	Memorandums	Bulletins
Everyday contact	Reports	Manuals
Training service	Letters	
Talks & assemblies	Job instruction	

Staffing begins with interviews, selection of personnel, orientation, starting the employee off on the right track. I cannot overemphasize the point of looking at yourself to discover your own prejudices, then try not to let them influence your judgment. During an interview it is important to be friendly and at ease with the individual as much as possible. Be cautious about using questions with a "yes" or "no" answer. Ask what we call "open end" questions. The person being interviewed should also feel free to ask questions. The interviewer should not place himself in a position where he does all the talking. After all, we are trying to find out information about the individual which is of utmost importance to the employer. New employees should be oriented completely about their job and duties pertaining to the organizational role.

1. Don't try to overwhelm the new employee with facts, figures and organizational charts.
2. Don't try to introduce him to all the employees in the organization in one day.
3. Don't forget the new employee after the first day.
4. Don't be afraid to commend an employee and praise the work, rather than the employee.
5. Don't take the older employee for granted. This principle has proven itself to me as a personal experience when supervising a division in our organization.
6. Be alert and recognize symptons as warnings of new problems.

Communication and public relations are closely associated because they deal with the public as a whole, the community, the state, the nation. However, in another sense of the word there are literally thousands of publics. Public relations is not only educating them, but also influencing their opinions. Every person in an organization should recognize his role in communications and public relations, and this should be a day to day activity for everyone. Public agencies have a difficult time because the people of this country have a basic dislike and distrust for government. This is why employees should have a complete understanding of their role in their organization.

Every organization should constantly ask itself how well its functions are understood. Group meetings are very important and every individual should have a chance to express his ideas and opinions. Maintain a straight forward relationship with all the media and especially with the newspaper. News should not be hidden or managed, and serious problems should be interpreted in a way that prevents any misunderstanding. A retraction or modification is worthless and will create more problems than it will solve. Acknowledge mistakes, rectify them and don't put any of your associates on the spot. Learn to write and speak, knowledge is doubling every five years and many people do not understand the problems of today because they have not kept up with their education.

Training

Training is an integral part of a supervisor's job. Without the supervisor's interest and participation, training efforts are very likely to be unsuccessful, indeed he is the key man implementing almost all of management's functions. He is also called the middle man, although he is on the management's team, he must be employee-centered. He must have the trust and confidence of those assigned to his work unit. Before a supervisor can become an effective trainer, both he and the organization must recognize and understand the nature of his job.

There should be a well organized program for training pre-supervisors who are about to assume supervisory duties. Supervisors make or break the organization. They have a responsibility to themselves and to the public to engage in self-development to the greatest extent possible. The supervisor should also learn to train his boss. He should learn the aggressions and defenses of his boss and understand the boss's needs. He should learn to present facts and communicate in the best way possible. Do not forget the older employees, have a program for job improvement, work simplification, new methods, new policies and new procedures. Remember that the best advertisement an organization can have is a satisfied employee.

Discipline means many things to many people. I would like to point out that discipline is also positive as well as negative and people within a unit can exercise self-discipline. Supervisors, like all other people, are conditioned by their past learning and experiences and their behavior is molded by their experiences. Therefore, the supervisor should understand his value system and try to be objective in dealing with problems requiring disciplinary action.

Defensiveness is a symptom of anxiety and frustration within an individual. As a supervisor you may not know what is causing this condition, but you should learn what every doctor knows, that one hardly ever cures a disease by treating the symptoms. Everyone is defensive at sometime or another. Learn to recognize defensiveness in yourself and you will have a much greater chance of success in making a good employee out of a person who has been a problem.

A corrective interview must be complete and the employee must be aware of the seriousness of his conduct, also that he knows he has a problem and complete understanding by the employee of what is acceptable. There are many do's and don'ts included in a corrective interview which are pertinent in achieving our goals. Proper discipline is the best for all.

Private business and corporation structures measure their results by profits, but we as a governmental enterprise cannot do this. Since service is our product, one of the goals of every public organization should be to provide more service per dollar. So by improving our entire operation, reducing cost through work improvement, we will be able to give more service per dollar. So feel important, be proud of your organization and remember the image you create is what you are.

SOURCE REDUCTION APPROACHES

Fred A. Compiano
San Joaquin Mosquito Abatement District, Stockton

In preparing this talk, I realized that there are approximately sixty mosquito abatement districts in California, and that out of the sixty mosquito abatement districts, eighteen have a source reduction department. I have had the pleasure of visiting some of these districts and have gained a great deal of information regarding their source reduction program. Some of the districts I have visited approach source reduction problems of eliminating mosquito sources by the installation of drains, dairy ponds, return flow systems, etc., with district owned and operated equipment. Other districts that have had similar programs have abandoned these practices.

Approaches to source reduction have been discussed many times at source reduction committee meetings; papers and talks have been presented at CMCA conferences by district managers, trustees, and source reduction personnel from different districts regarding the different approaches used; such as legal, educational, and cooperative projects between districts and property owners.

The San Joaquin Mosquito Abatement District has a source reduction policy, adopted in 1959, which has been printed in the Proceedings and Papers of the 36th Annual Conference of the CMCA held in Fresno, California, January 29-31, 1968, and has over the past years approached source reduction as governed by the statements of this policy.

Our approach has been as follows: (1) records are kept at the district office, showing cost of treatment on each source, including material used and labor for application of material; (2) during the winter months district supervisors contact each property owner and record in report form type of source, area of standing water, location, name and remarks of property owner; (3) each report is evaluated by two full-time source reduction employees and the manager; (4) major sources are surveyed, maps made showing reason for type of source, elevations of land, possible drainage outlets (if drainage is solution); (5) each year letters are mailed to property owners informing them of cost of treating sources and requesting their cooperation; in most cases, these property owners are contacted by source reduction personnel; (6) where large areas lack proper drainage, the San Joaquin MAD will, and has conducted engineering surveys, resulting in the formation of two drainage districts; in addition, land leveling permits issued for excavation of earth, soil or construction materials are reviewed by the San Joaquin MAD; and, (7) district supervisors are requested to report, in writing, any new sources that may occur during the summer to the source reduction department.

In addition, other agencies, such as State Reclamation Bureau, U.S. Corps of Engineers, irrigation districts, flood control districts, County Public Works and Planning Department must be made aware of mosquito sources they may create, through the planning and design on projects pertaining to sloughs, rivers and highway construction.

Good public relations with district employees and the general public is a very important factor; last but not least, know your subject before approaching any source reduction problem.

For an example, approaches to agricultural sources are established as follows: field investigation of source, including crops grown, drainage facilities, if any, soil type, land grades, return flow system, if economical, water management, irrigation district, drainage district, reclamation district, etc., and areas adjacent to the problem area.

COST ANALYSIS COMPARISONS IN MOSQUITO SOURCE REDUCTION

Richard C. Husbands
Bureau of Vector Control and Solid Waste Management
California State Department of Public Health, Fresno

A basic operation in any business is the analysis of operational benefits and costs (profits and losses). Where do we stand in mosquito control in this regard?

Until recently the primary effort in mosquito control has been focused almost entirely upon the job of getting positive and immediate results. Insecticides were the most economical and successful means of achieving this public health objective. Chemical mosquito control was a necessary price to pay for the immediate benefits obtained, but it was never one to be paid complacently. The "price" in chemical control operations now include: a gradual loss of mosquito population susceptibility to useful toxicants, a disproportionate increase in associated costs (Figure 1), a more rigid public attitude toward chemical pollution hazards, and an increasingly complex legal pressure involved in the handling, distribution, and consequences of chemical usage. These escalating problems and others may eventually "price" us out of the present methods used in mosquito control.

We are now faced with a challenge to re-examine our objectives and to determine if future problems and costs can be reduced. A major part of this solution depends upon the development of a control technology that works with and not against the environment. The early wisdom of identifying mosquito control with the basic principles of "source reduction" becomes more apparent today. And one of the logical ways to evaluate progress in mosquito control is to place a measurable value on the methods used to solve problems. This is best illustrated by the principle of cost-benefit analysis.

Cost benefits that are derived from mosquito source reduction operations are difficult to measure. Basically, there are three benefits: one is the improved production or profit that results on the land or within the system; two is the reduced cost that is sometimes derived from a reduction in the chemical treatment of the problem or source; thirdly, but more difficult to assess in dollars and cents value, is the ecological, aesthetic, and health benefits obtained by the operation. And it should be remembered that health benefits are the main objective of mosquito control and for that reason should be placed above all other priorities and benefits.

Source reduction projects require sound analysis and the application of each of these basic benefits whenever they can be applied. "Costs" can be determined without much effort; however, "benefits" can be of great variety and character and they usually increase in value in time and therefore are difficult to measure. A cost-benefit ratio is sometimes useful in justifying a source reduction project but it is not recommended as the basis for determining the priority of work. Other tangible and intangible values may have greater priority significance and each project should be judged on the basis of its contribution to progress in source reduction under the conditions and policies prevailing at the time.

In some cases, projects can be divided into "reimbursable" and "nonreimbursable" costs. Reimbursable costs are those selected capital outlays that can be repaid by the economic benefits or savings that will be returned to the budget, for example, insecticide, labor, and equipment savings. To determine these benefits, it is sometimes justifiable to compute the estimated "savings" to cover a period of time (from 10 to 50 years). Nonreimbursable costs may include administrative and engineering planning, easements, fish and wildlife protection, recreation and flood control.

Figure 1. The disproportionate effect of increasing the cost of chemical mosquito control.

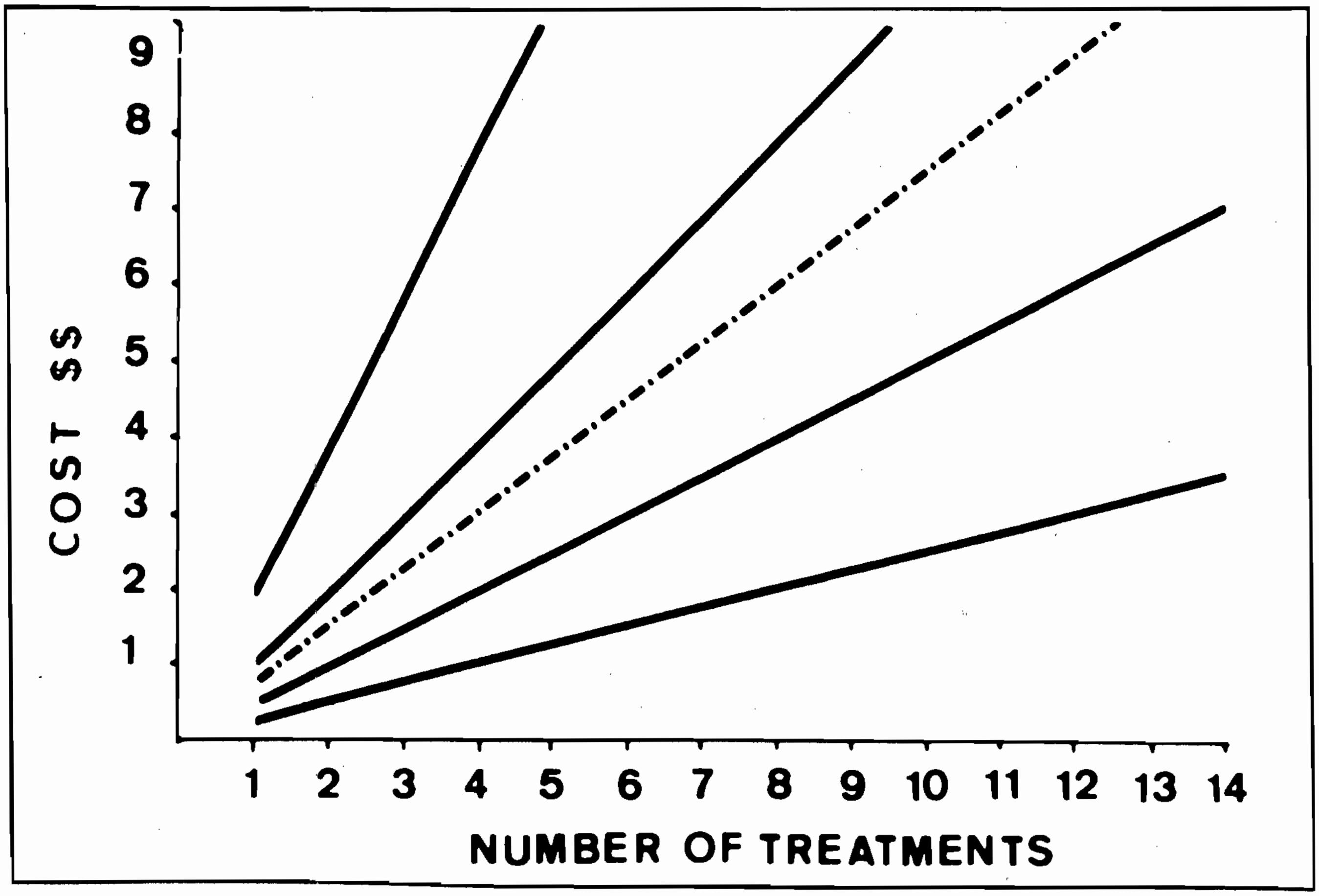
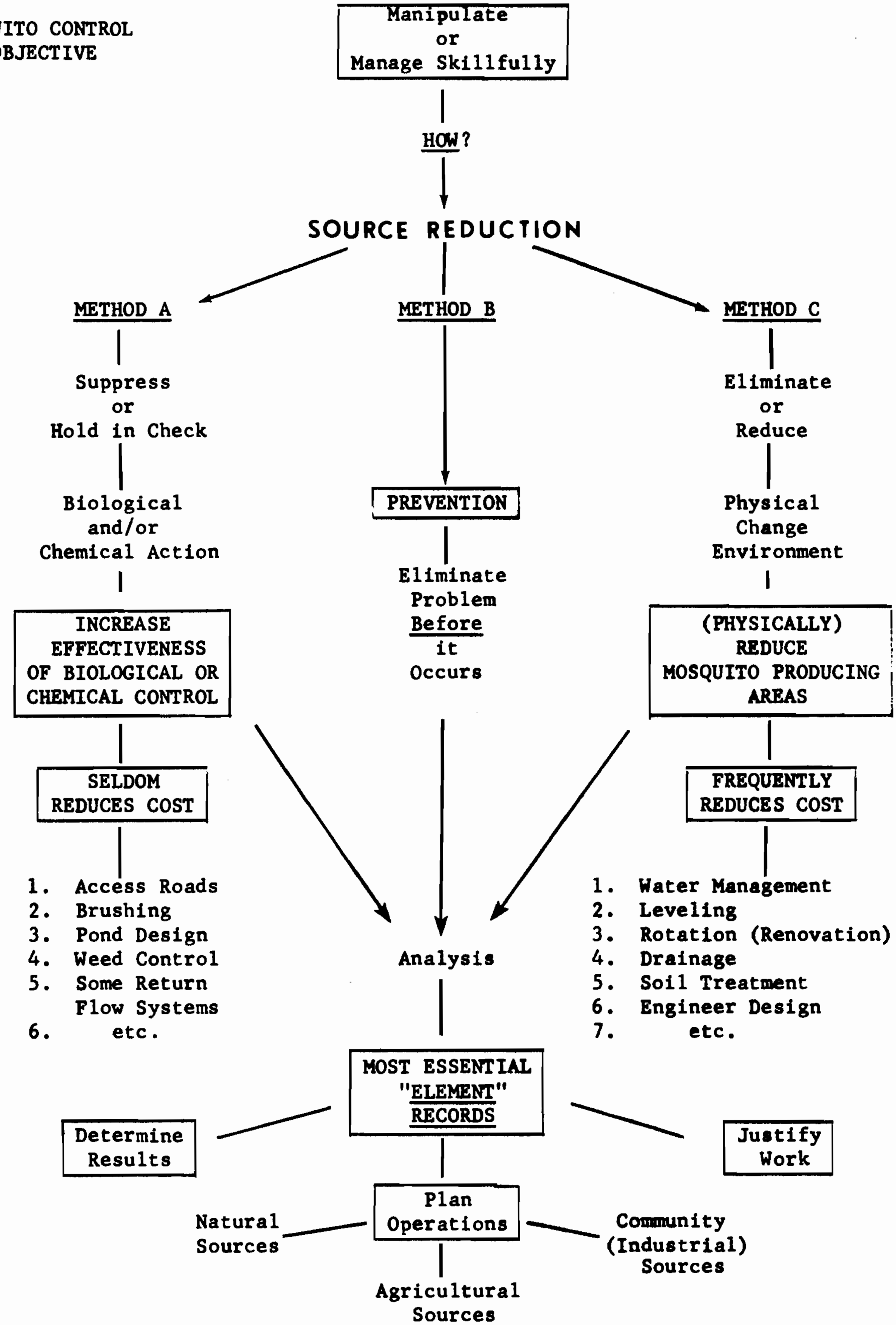


Figure 2

MOSQUITO CONTROL OBJECTIVE



In addition, auxiliary benefits, which are of great importance in selling the source reduction work, are associated with some projects. These benefits are the profits or gains derived from the work by the person or agency contracting with the district for the project. It is questionable whether this type of benefit may be used as a district justification for mosquito source reduction.

Source reduction can be approached by three basic methods: (A) suppression, (B) prevention, and (C) elimination (Figure 2). Suppression can be used to improve the efficiency of control by increasing the effectiveness of chemical or biological abatement methods through proper modification of the environment to enhance this activity. In some cases, these suppressive methods can show auxiliary benefits. As an example, it has been estimated, probably quite conservatively, that it costs $10.00 per bird to put a duck in the bag. If waste water is diverted into properly constructed ponds to minimize mosquito production and at the same time to provide wildlife and recreation, it is possible to estimate the value received from the game taken. If one bird is taken per acre, it generates an economic return of $10.00 per acre. Capitalized at 5%, the land might be said to be worth $200.00 per acre. One operation in Kern County, leasing one section, 640 acres, grosses around $35,000 per year. We should not discount the economic benefits that can be derived from the use of waste water for wildlife production and if this is attributed to source reduction planning and effort, the benefits should be recorded as a justified way of selling source reduction. If the project also reduces the cost of chemical control it is a reimbursable cost benefit. I call your attention to the excellent work which has been done in Utah under the direction of Dr. Rees (1969) and others that has demonstrated some of the environmental improvements which will reduce mosquitoes and improve waterfowl management. Fishing can be equally profitable. Reservoirs that are built to contain irrigation or waste water can show an economic benefit. In San Diego County, a privately leased lake with a fee of $1.50 per day per fisherman has grossed up to $300,000 a year and never less than $190,000 on a dry year. We are all aware of the aesthetic and recreational value of the Santee Project (Merrell et al. 1967). The application of these same reclamation principles in source reduction are extremely valuable and should be used wherever possible. When you look at all the excess wasted water that produces mosquitoes think of it as money wasted.

Prevention should not be overlooked in cost analysis. If source reduction principles are used to correct the problem before it occurs, then the time spent in man-hours that helps to prevent a mosquito source can be balanced against average district costs normally associated with an uncorrected problem of this type. This will require some bookkeeping but the results will be very gratifying when summarized periodically. It represents a gain which continues to grow in value as time passes. A report on prevention and an estimate of monies saved should be very impressive, especially when shown to taxpayers or to trustees.

Elimination normally shows a reduction in area treated, number of treatments, or species treated. Source reduction records should show reductions in the cost of chemical control; however, these reductions will vary greatly, reflecting the formula used for estimating preliminary control costs. Carefully analyzed biological and physical guidelines should

Figure 3. Reimbursement rate (chemical control savings) computed for eleven source reduction projects constructed by the Kings Mosquito Abatement District.

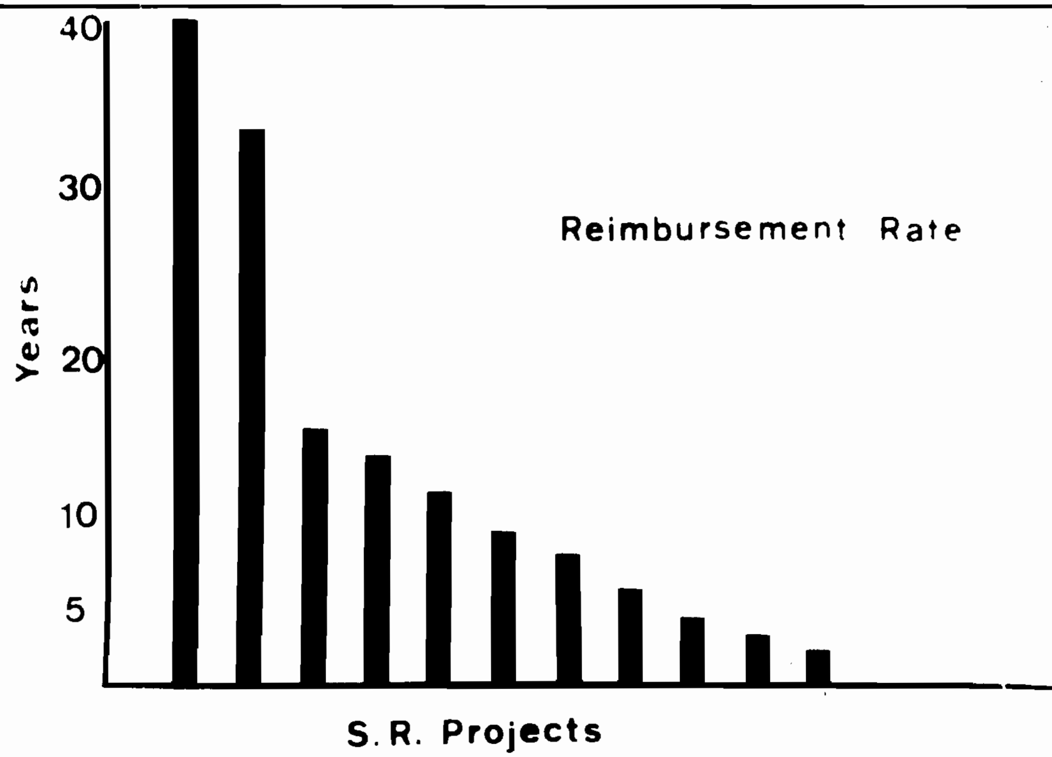
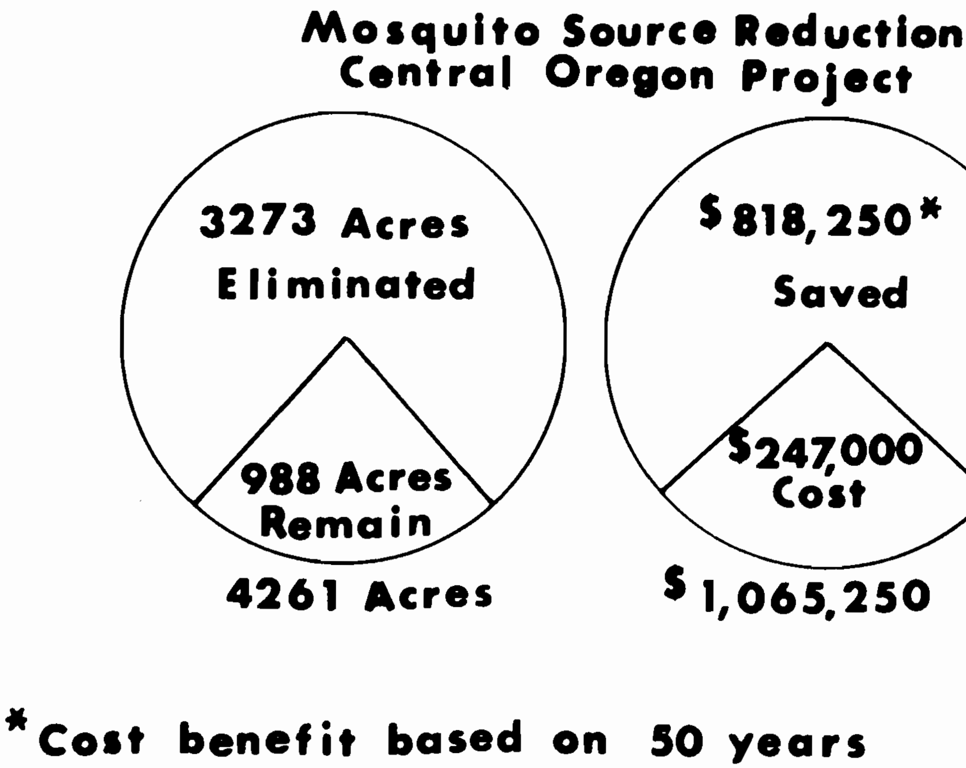


Figure 4. Estimated economic and acreage benefits in mosquito control associated with the development of the Crooked River Irrigation Project, Central Oregon.



be used to determine these costs. As an example, Figure 3 illustrates the rate of reimbursement recorded for 11 source reduction projects that were constructed in the Kings Mosquito Abatement District. These estimates were based upon the average chemical treatment costs recorded for each project from 1962 to 1969. The graph shows that reimbursement of these costs per project will range from 3 to 42 years, with a majority (9) of the projects being repaid from benefits (savings in chemical control) in less than 16 years. Over half will be repaid in less than 10 years. In 10 years the 11 projects will have saved the District approximately $5000 in chemical and inspection costs. Actually the savings are even greater than this because chemical application costs will increase during the 10 years and administrative and technical overhead will automatically reduce during the period used to estimate the savings.

An illustration of the value gained from a major source reduction project is shown in Figure 4. This Central Oregon project (Anon. 1968) eliminated 3273 acres of mosquito production in a farming area where annual cost for mosquito control was about $5.00 per acre. After source reduction the annual savings for the area was about $16,360. Without the benefits of source reduction it was estimated that in 50 years mosquito control in this area would have cost $1,065,250. After source reduction the cost was reduced to $247,000. Other benefits were derived from this project, such as increased farm production and a reduced hazard in disease transmission.

Although source reduction is only one of several potential ways of reducing mosquito control costs, it is apparent that future mosquito abatement programs must expand in this direction. Actually, we have no choice but to overcome deficiencies in the environment that contribute to continuing and rising costs. Cost-benefit records are an essential element in this program and will help to justify and identify where we should put our efforts. We cannot afford to conduct our business at a loss.

References Cited

Anon. 1968. Report on a study of mosquito problems associated with development of the Crooked River Irrigation Project, Central Oregon, 1960-1966. Aquatic Plant and Weed Control Committee, Pacific Northwest River Basins Commission, Water Resources Council, 30 p.

Merrell, John C., Jr., W.F. Joplin, R.F. Bott, A. Katko, and H.E. Pintler. 1967. The Santee recreation project, Santee, California. U.S. Dept. Interior, Fed. Water Pollution Control Adm., Water Pollution Control Research Series, Publ. No. WP-20-7. 165 p.

Rees, D.M. 1969. Insect pests and vectors on waterfowl marshes in Utah and non-chemical abatement. Center of Environmental Biology University of Utah, Salt Lake City, Utah. 103 p.

CONTEMPORARY CONSIDERATIONS ON THE BIOLOGICAL SUPPRESSION OF NOXIOUS BRACHYCEROUS DIPTERA THAT BREED IN ACCUMULATED ANIMAL WASTES[1]

E. F. Legner
Division of Biological Control, University of California, Riverside

During the past two decades a number of basic research achievements in the integrated control of noxious brachycerous Diptera breeding in accumulated wastes have occurred which enhance the possibilities for the good abatement of such flies. Earlier workers, because of their particular specialities and localities, placed more emphasis on certain biotic agents such as predaceous flies, ants and competing flies that were of high control value in restricted areas (Furman et al. 1959, Anderson and Poorbaugh 1964b, Kilpatrick and Schoof 1959, and Pimentel 1955), or mites which were characteristically widespread in humid temperate areas (Axtell 1962, 1968; Rodriquex and Wade 1961, Willis and Axtell 1968). Most predatory species and the wasp-like parasitoids were at first largely ignored, or were credited with little, if any, role in the population dynamics of noxious flies.

Experimental research during this period, directed at controlling immature stages of flies with larvicides, regularly showed 100 percent control; but in applied abatement the desired level of control was rarely achieved. The number of papers treating larvicides during the last 20 years is too large to cite; but one characteristic shared by most reported experiments was the translocation of the breeding site to isolated emergence units, thereby removing them from further replenishment. The percentage kill in such cases was usually much greater than would have been expected could the breeding sites have remained in a dynamic state of replenishment, as occurs under most conditions. In the latter case, larvicides are quickly buried below the fly larval feeding level as new deposits are added from above. Larvae feeding in the fresh deposits above the insecticide layer are largely free to complete their development to maturity. However, predatory arthropods, which forage frequently throughout breeding site deposits, are largely eliminated because of repeated contacts in the larvicide stratum. Since many predators are univoltine, their numbers are not very rapidly replaced. The removing of the breeding site in experiments to allow for adult fly emergence also disturbs these natural enemies, causing them to flee, and in the check portions of experiments cease feeding activities.

Considerations of hosts evolving resistance were impossible to make because of the characteristically short term of these experiments; in field breeding fly populations resistance invariably caused unpredicted responses.

Fly resistance to insecticides was shown early by Bruce and Decker (1950) and Decker and Bruce (1951); and later further elaborations were discussed by Georghiou (1966). These studies indicated that fly populations develop resistance to insecticides quicker if individuals are killed as larvae than as adults, and that resistant populations are capable of spreading to other breeding sites.

[1]Research was conducted during the tenure of Grant Nos. GM 12699 and GM12496, National Institutes of Health U.S.P.H.S.

Early studies in the Soviet Union (Derbenev Ukhova 1942) and recent work in Denmark (Arevad 1965, Keiding 1965; Mourier 1964), and California (Anderson 1964, Anderson and Poorbaugh 1964a) provided detailed information on the ethology of adult pestiferous flies that emphasized the value of destroying females before their population pressures drove them into residential areas to manifest their nuisance role. The habits of recently emerged adults of some species to alight repeatedly on walls and rafters in the immediate vicinity of their immature breeding grounds presented an obvious advantage to fly abatement. If such surfaces were treated with residual contact insecticides, adults could be killed before they left the breeding premises. An overall reduction in the adult population without a subsequent reduction of natural enemies that do not possess this habit of alightment could, then, result in a general lowering of the threshold density of fly breeding. The kinds of natural enemies and a discussion of the intricacies of some of the dynamics involved are reported in Kogan and Legner (1970), Legner (1965, 1967), Legner and Brydon (1966), Legner and Greathead (1968), Legner and Olton (1968a, 1968b, 1970a, 1970b), Legner et al. 1967, and Peck 1968.

In southern California there occur numerous practical demonstrations of integrated fly control in Orange and San Bernardino counties, where the respective county health departments are directly involved in supervision (Legner and Olton 1968a). Two prerequisites for successful abatement are proper manure management and the thorough application of peripheral residual adulticides at one or two critical times of the year. Both of these operations require experience and awareness that (1) natural forces never result in the extinction of cosmopolitan pests, and (2) that natural balance is ever capable of being upset by man's involvement.

References Cited

Anderson, J.R. 1964. The behavoir and ecology of various flies associated with poultry ranches in northern California. Proc. Calif. Mosq. Control Assoc. 32:30-34.

Anderson, J.R., and J.H. Poorbaugh. 1964a. Observations on the ethology and ecology of various Diptera associated with northern California poultry ranches. J. Med. Ent. 1(2): 131-147.

1964b. Biological control possibility for house flies. Calif. Agric. 18(9):2-4.

Arevad, K. 1965. On the orientation of houseflies to various surfaces.Ent. Exptl. and Applied. 8:175-188.

Axtell, R.C. 1962. Macrochelidae (Acarina: Mesostigmata) inhabiting manure and their effect on housefly production. Ph.D. Thesis, Cornell University, Ithaca, N.Y.

1968. Integrated housefly control: populations of fly larvae and predaceous mites, *Macrocheles muscaedomesticae*, in poultry manure after larvicide treatment. J. Econ. Ent. 61(1):245-249.

Bruce, W.N., and G.C. Decker. 1950. House fly tolerance for insecticides. Soap Sanit. Chem. 26(3):122-125, 145-147.

Decker, G.C., and W.N. Bruce. 1951. Illinois Natural History Survey research on house fly resistance to chemicals. In Conference on Insecticide Resistance and Insect Physiology, National Academy of Sciences National Research Council. U.S. Publ. 219:25-33.

Derbenev-Ukhova, B.P. 1942. On the development of ovaries and on the imaginal nutrition in dung flies (in Russian). Medical Parasitology (Parazitarn. Bolezn. U.S.S.R.) 11:85-97 Rev. Appl. Ent. 1944b. 32:118.

Furman, D.P., R.D. Young and E.P. Catts. 1959. *Hermetia illucens* (Linn.) in natural control of *Musca domestica.* J. Econ. Ent. 52(5):917-921.

Georghiou, G.P. 1966. Distribution of insecticide-resistant house flies on neighboring farms. J. Econ. Ent. 59(2):341-346.

Keiding, J. 1965. Observations on the behaviour of the housefly in relation to its control. Rivista de Parassitologia 26(1):45-60.

Kilpatrick, J.W. and H.F. Schoof. 1959. Interrelationship of water and *Hermetia illucens* breeding to *Musca domestica* production in human excrement. Amer. J. Trop. Med. Hyg. 8(5): 597-602.

Kogan, M. and E.F. Legner. 1970. A biosystematic revision of the genus *Muscidifurax* Girault and Sanders (Hymenoptera: Pteromalidae) with descriptions of four new species. Canad. Ent. (In press, 1970).

Legner, E.F. 1965. Un complejo de los artropodos que influyen los estadios juveniles de *Musca domestica* L. en Puerto Rico. Carib. J. Sci. 5(3-4):109-115.

1967. The status of *Nasonia vitripennis* as a natural parasite of the house fly, *Musca domestica.* Canad. Ent. 99(3):308-309.

Legner, E.F. and H.W. Brydon. 1966. Suppression of dung inhabiting fly populations by pupal parasites. Ann. Ent. Soc. Amer. 59(4):638-651.

Legner E.F. and D.J. Greathead. 1969. Parasitism of pupae in East African populations of *Musca domestica* and *Stomoxys calicitrans.* Ann. Ent. Soc. Amer. 62(1):128-133.

Legner, E.F. and G.S. Olton. 1968a. The biological method and integrated control of house and stable flies in California. Calif. Agric. 22(6):1-4.

1968b. 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. Ent. Soc. Amer. 61(5):1306-1314.

1970a. Populations of adult insect predators and scavengers associated with animal manure accumulations obtained from world-wide collection sites compared. Hilgardia (in press, 1970).

1970b. Distribution and relative abundance of Diptera and their parasitoids inhabiting animal manure accumulations in the southwestern United States. Hilgardia (in press, 1970).

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 Eastern Hemisphere. Ann. Ent. Soc. Amer. 60(2):462-468.

Mourier, H. 1964. Circling food-search behaviour of the house fly (*Musca domestica* L.) Vidensk. Meed. fra Dansk naturh. Foren. bd. 127:180-194.

Peck, J.H. 1968. The potential role of arthropod predators in the integrated control of Diptera developing in poultry droppings. Ph.D. Thesis, University of California, Berkeley, California.

Pimentel, D. 1955. Relationship of ants to fly control in Puerto Rico. J. Econ. Ent. 48(1):28-30.

Rodriguez, J.G. and C.F. Wade. 1961. The nutrition of *Macrocheles muscaedomesticae* (Acarina: Macrochelidae) in relation to its predatory action on the house fly egg. Ann. Ent. Soc. Amer. 54(6):782-788.

Willis, R.R. and R.C. Axtell. 1968. Mite predators of the housefly: a comparison of *Fuscuropoda vegetans* and *Macrocheles muscaedomesticae.* J. Econ. Ent. 61(6):1669-1674.

ADVANCES IN THE ECOLOGY OF *HIPPELATES* EYE GNATS IN CALIFORNIA INDICATE MEANS FOR EFFECTIVE INTEGRATED CONTROL[1]

E. F. Legner
Division of Biological Control, University of California, Riverside

Of the seven species of *Hippelates* eye gnats in California, one species, *H. collusor* (Townsend), continues to be of wide spread primary concern. Being directly involved with agricultural practices, it is also the only species of these pests that is presently capable of being manipulated through integrated control practices. Such species as *H. robertisoni* Sabrosky and *H. impressus* Becker, of sporadic importance in recreation areas, are not subject to control by other than pure biological means. The reproduction of these latter two species in undisturbed wild breeding sites precludes the interjection of both chemical and cultural control methods.

The importance of *H. collusor* in public health has caused a focusing of attention on this species for over 40 years in California. Detailed information has accumulated on its flight range (Mulla and March 1959), distribution (Burgess 1935; Mulla 1964; Womeldorf and Mortenson 1962), breeding habits (Burgess 1951; Legner 1968; Legner et al. 1966; Mulla 1962c, 1963; Tinkham 1952), biology (Adams and Mulla 1967a, 1967b; Burgess 1951; Dorner and Mulla 1961, 1962; Hall 1932; Herms 1926; Legner 1966; Legner and Olton 1969; Mulla 1962b), and native and imported natural enemies (Bay and Legner 1963; Bay et al. 1964; Legner 1967, 1968; Legner and Bay 1964, 1965; Legner and Olton 1969; Legner et al. 1966a, 1966b; Mulla 1958, 1962a). This research has produced knowledge necessary for the effective reduction in pest status of the *Hippelates* eye gnat. However, such reduction requires a thorough understanding of eye gnat ecology; and it is clear that a community-wide effort is necessary to attain a satisfactory lower population density of *Hippelates.*

Integrated Control Procedure

The following procedure for integrated eye gnat control is based on a considerable volume of both published and unpublished research, that has accumulated through the efforts of many scientists over the past 40 years. Details are too involved and numerous to present here; however, attention is invited to cited references which provide the information required.

Non-cultivation, which has been emphasized by scientists for over 40 years, is still recognized as a principal requi-

[1]Research was conducted during the tenure of Grant No. 12496 of the National Institutes of Health, U.S.P.H.S.

site for decreasing eye gnat population densities (Hall 1932; Burgess 1955, 1951; Tinkham 1952; Mulla 1963). Contemporary research has merely made us more aware of the dynamic processes involved without providing us with a more effective solution. One thing is clear: it is not merely the decrease in available food through non-cultivation that causes reduced breeding.

When cultivation is required, as it appears to be in certain row crops; evidence suggests that it be conducted at night or on days when the temperature is below 65° F, or on windy days when wind velocities exceed 2 mph: times when eye gnat flight is at a minimum (Dorner and Mulla 1962; Legner unpublished data; Mulla and March 1959). Exposure of the cultivated soil to the open air progressively renders it unattractive to ovipositing females, so that several hours later it has lost most of its attractiveness.

The maintenance of an orchard cover of mature, hardened plants which can be kept low by mowing, is much preferred (Legner 1968; Mulla 1963; Tinkham 1953). The maintenance of permanent stands of vegetation decreases gnat oviposition and larval survival, and does not interfere with the activities of soil predators and parasites (Legner 1968; Legner unpublished data).

In cases of localized gnat abundance, the use of any means of reducing the adult eye gnat population, such as poison baits or aerosol insecticides should be recognized as advantageous. Such measures are not harmful to the processes of natural gnat reduction, and in theory could result in an overall lowering of the threshold of eye gnat breeding.

References Cited

Adams, T.S. and M.S. Mulla. 1967a. The reproductive biology of *Hippelates collusor* (Diptera: Chloropidae). I. Morphology of the reproductive systems with notes on physiological aging. Ann. Ent. Soc. Amer. 60(6):1170-1176.

1967b. The reproductive biology of *Hippelates collusor* (Diptera: Chloropidae). II. Gametogenesis. Ann. Ent. Soc. Amer

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. Ent. Soc. Amer. 57(5):582-584.

Burgess, R.W. 1935. The eye gnat in the Coachella Valley, California. U.S. Dept. Agr. Bur. Ent. Plant Quar. E335:1-7.

1951. The life history and breeding habits of the eye gnat *Hippelates pusio* Loew in the Coachella Valley, Riverside County, California. Amer. J Hyg. 53(2):164-177.

Dorner, R.W. and M.S. Mulla. 1961. Response of the eye gnat *Hippelates collusor* to light of different wave lengths. Ann. Ent. Soc. Amer. 54(1):69-72.

1962. Laboratory study of wind velocity and temperature preference of *Hippelates* eye gnats. Ann. Ent. Soc. Amer. 55(1): 36-39.

Hall, D.G., Jr. 1932. Some studies on the breeding media, development and stages of the eye gnat *Hippelates pusio* Loew (Diptera: Chloropidae). Amer. J. Hyg. 16(3):854-864.

Herms, W.B. 1926. *Hippelates* flies and certain other pests of the Coachella Valley, California. J. Econ. Ent. 19(5):692-695.

Legner, E.F. 1966. Competition among larvae of *Hippelates collusor* (Diptera: Chloropidae) as a natural control factor. J. Econ. Ent. 59(6):1315-1321.

1967. Two exotic strains of *Spalangia drosophilae* merit consideration in biological control of *Hippelates collusor* (Diptera: Chloropidae). Ann. Ent. Soc. Amer. 60(2):458-462.

1968. Parasite activity related to ovipositional responses in *Hippelates collusor*. J. Econ. Ent. 61(5):1160-1163.

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. Ent. Soc. Amer. 57(6): 767-769.

1965. Predatory and parasitic agents attacking the *Hippelates pusio* complex in Puerto Rico. J. Agric. Univ. Puerto Rico 49(3):377-385.

Legner, E.F. and G.S. Olton. 1969. Migrations of *Hippelates collusor* larvae from moisture and trophic stimuli and their encounter by *Trybliographa* parasites. Ann. Ent. Soc. Amer. 62(1):136-141.

Legner, E.F., G.S. Olton and F.M. Eskafi. 1966. Influence of physical factors on the developmental stages of *Hippelates collusor* in relation to the activities of its natural parasites. Ann. Ent. Soc. Amer. 59(4):851-861.

Legner, E.F., E.C. Bay, and T.H. Farr. 1966a. Parasitic and predaceous agents affecting the *Hippelates pusio* complex in Jamaica and Trinidad. Can. Ent. 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. Ent. Soc. Amer. 59(5):977-984.

Mulla, M.S. 1958. Control of mites in laboratory cultures of the eye gnat, *Hippelates collusor* (Townsend). J. Econ. Ent. 51(4): 461-462.

1962a. Recovery of a cynipoid parasite from *Hippelates* pupae, Mosquito News 22(3):301-302.

1962b. Mass rearing of three species of *Hippelates* eye gnats (Diptera: Chloropidae). Ann. Ent. Soc. Amer. 55(2):253-258.

1962c. The breeding niches of *Hippelates* gnats. Ann. Ent. Soc. Amer. 55(4):389-393.

1963. An ecological basis for the suppression of *Hippelates* eye gnats. J. Econ. Ent. 56(6):768-770.

1964. Seasonal population trends of *Hippelates* gnats (Diptera: Chloropidae) in southern California. Ann. Ent. Soc. Amer. 57(1):12-19.

Mulla, M.S. and R.B. March. 1959. Flight range, dispersal patterns and population density of the eye gnat, *Hippelates collusor*. Ann. Ent. Soc. Amer. 52(6):641-646.

Tinkham, E.R. 1952. The eye gnats of Coachella Valley with notes on the 1951 larviciding program. Proc. Calif. Mosq. Control Assoc. 20:83-84.

Womeldorf, D.J. and E.W. Mortenson. 1962. Occurrence of eye gnats (*Hippelates* spp.) in the central San Joaquin Valley, California. J. Econ. Ent. 55(4):457-459.

POPULATION CYTOGENETICS OF *ANOPHELES FREEBORNI* AITKEN
A PRELIMINARY REPORT

T. W. Smithson
Department of Entomology, University of California, Davis

Introduction

In working with living organisms taxonomic recognition of a species may not imply enough about the biology of the population involved. Characterization at this level may be enhanced by genetic analysis. Observable differences in behavior or ecology are reflections of genetic differences; this recognition can lead to a better understanding of the species and a more direct approach to control. Two such examples include the work on the European *Anopheles maculipennis* (Frizzi 1956) and with *Anopheles gambiae* (Coluzzi and Sabatini 1968).

The most direct method for genetic characterization of a population is by cytogenetic analysis. As pointed out by Spielman and Kitzmiller (1967), such a tool allows the recognition of subtle genetic differences and relationships. The observation of the authors was more than borne out by the classical work of Dobzhansky and Epling (1944) on salivary gland chromosome polymorphism in populations of *Drosophila pseudoobscura*; studies which revealed ecotypes within a single taxonomic species. Dobzhansky also showed these ecotypes capable of altering their genome in response to seasonal or other environmental changes. The fact that these ecotypes exist and have the capability to alter their genome in response to changes in the environment is significant not only to the evolution of the species, but to its reaction to induced selection pressures.

Chromosome polymorphism of the type shown by *Drosophila* is not unique to this group, but may be demonstrated in other Diptera including *Anopheles* mosquitoes. To date, however, this polymorphism has only been used in the separation of the sibling species complexes of *A. maculipennis* and *A. gambiae* and has had little application to the ecology of *Anopheles* mosquitoes.

Kitzmiller and Baker (1963) in their paper describing the salivary gland chromosomes of *Anopheles freeborni* mentioned that chromosome polymorphism existed in the laboratory material they were using and Kitzmiller (1963) in a later paper suggested that a field situation similar to *Drosophila* might exist in *A. freeborni*. The present study of *A. freeborni* was initiated to try to answer a number of questions. First, does chromosome polymorphism exist in the field population? Second, if polymorphism exists in the field populations, will comparisons of different populations reveal the presence of ecotypes and possible seasonal differences within individual populations? Third, can significant differences in populations be correlated with known ecological data?

Materials and Methods

In the initial phase of the study in 1968, larvae and adults of *A. freeborni* were collected at various times from populations in the upper Sacramento Valley. Adult females were separated into blood engorged or gravid and unfed groups. Unfed females were allowed to take a blood meal, those that did, along with the females from the other group, were placed in individual ovipositional containers. The field collected larvae and eggs from the adult material were reared under standard methods to early fourth instars. Salivary gland preparations were made according to the methods described by French, Baker and Kitzmiller (1962). These preparations were then compared with the standard chromosome map of *A. freeborni* as proposed by Kitzmiller and Baker (1963). The second phase of the study was initiated during the 1969 breeding season. During this time weekly field collections were made of adult populations along an east-west transect of the Sacramento Valley. A minimum of 25 females were collected from each of the sampled populations at Browns Valley (Yuba Co.), Sutter (Sutter Co.), and Williams (Colusa Co.). These were returned to the laboratory and processed as described with a minimum preparation of five larvae from the eggs of each female collected.

Results and Discussion

The collections and preparations during 1968 confirmed the laboratory observations of Kitzmiller that chromosome polymorphism exists in *A. freeborni* and that it may be found in field populations. The only consistant character found is a heterozygous inversion in the right arm of the third chromosome between regions 29A and 31A (see Plate 1, Kitzmiller and Baker 1963).

In the 1969 study an attempt was made to compare the polymorphism of different populations and determine if there were seasonal intrapopulation differences. In this phase of the study, however, a problem developed. Specifically, the number of completely readable preparations from each sample were running about six percent of the total and at times entire samples gave no usable data. This problem has resulted in insufficient data on the frequency of the three possible combinations of the polymorphic region of the third chromosome (normal homozygote, heterozygote and inverted homozygote). Without this information it has been impossible to determine if there are seasonal differences in the individual populations studied. The study of the allopatric populations, based on the frequency of the heterozygous inversion described above, was continued though the results were not as reliable as desired.

The presence of the heterozygous state for the inversion in the third chromsome is easily detected by the presence of an inversion loop (see Figure 1, Kitzmiller and Baker 1963) and was scored in all chromosome preparations where its presence or absence could be confirmed. Table 1 shows the frequency of this inversion in the populations studied. The observed preparations, as used in Table 1, are all preparations from different females and do not reflect the multiple preparations of larvae from each female. Based on the data available there appears to be little difference in the frequency of this character between the sampled populations, indicating genetic homogeneity in these populations for at least this character.

Table 1. Frequency of heterozygous inversions in chromosome III-R of three populations of *Anopheles freeborni.*

Population Sampled	No. Observed Preparations	Preparations With Inversions	
		Number	Percent
Williams	320	155	48.4
Sutter	212	97	45.8
Browns Valley	280	132	47.5

On-going efforts have been directed toward solving the preparation problem which is thought to be related to either rearing conditions or nutritional factors. To date these efforts have been unsuccessful, but this does not mean the study should be abandoned, only that it will require more time to amass sufficient data to make statements about individual populations.

Further studies of allopatric population differences will be along a north-south transect of the upper and lower Sacramento Valley.

The correlation of ecological data with various populations will have to await confirmation of the presence of ecotypes or demonstrated seasonal differences in chromosome patterns of populations of *A. freeborni.*

Acknowledgments

The author wishes to thank Mr. Eugene Kauffman, Manager, Sutter-Yuba MAD, and Dr. G.A.H. McClelland, University of California, Davis, for their advice and suggestions on this work. Dr. R.K. Washino who read the manuscript and offered many valuable suggestions is also gratefully acknowledged.

References Cited

Coluzzi, M. and A. Sabatini. 1968. Cytogenetic observations on species C of the *Anopheles gambiae* complex. Parassitologia 10(2-3):155-156.

Dobzhansky, Th. and C. Epling. 1944. Contributions to the genetics, taxonomy, and ecology of *Drosophila pseudoobscura* and its relatives. Carnegie Inst. Wash. Publ. 554. 183 pp.

French, W.L., R.H. Baker, and J.B. Kitzmiller. 1962. Preparation of mosquito chromosomes. Mosq. News 22:377-383.

Frizzi, G. 1956. Prolimorfisno cromosomico in Anopheles. Boll. Zool. 23:503-510.

Kitzmiller, J.B. and R.H. Baker. 1963. The salivary chromosomes of *Anopheles freeborni*. Mosq. News 23:254-262.

Kitzmiller, J.B. 1963. Mosquito cytogenetics. Bull. Wld. Hlth. Org. 29:345-355.

Spielman, A. and J.B. Kitzmiller. 1967. Genetics of populations of medically important arthropods. In J.W. Wright and R. Pal. Genetics of insect vectors of disease, Elsevier Publ. Co., New York. p. 459-485.

ECOLOGICAL STUDIES OF *HYDROPHILUS TRIANGULARIS* SAY IN THE LABORATORY AND IN A RICE FIELD HABITAT

A PRELIMINARY REPORT

R. Veneski[1] and R. K. Washino[2]

Hydrophilus triangularis Say, the water scavenger beetle, has been observed in varying numbers in rice fields in the Sacramento Valley of California. The larvae of this beetle are predaceous and the adults, grazers and scavengers. A comprehensive analysis of the feeding patterns of this beetle is lacking. Most of the earlier works (Saunders 1879; Garman 1881; Riley 1881; Matheson 1914) have been descriptive, relating to life history aspects and development. Wilson (1923) did a comprehensive study of the life history and described the larval feeding habits based on the dissection of fifty-two individuals. Clark (1938) reported that, in the laboratory, the larvae feed on mosquitoes.

In a preliminary survey in the Sacramento Valley, three of fifteen field-collected beetle larvae contained mosquito larvae in their digestive tract. To determine more clearly the role of *H. triangularis* as a predator of mosquitoes in rice fields, the feeding pattern as well as the general biology of this beetle was studied. The purpose of this report is to summarize the preliminary findings of the field and laboratory studies conducted in 1966 and 1969.

[1]Department of Life Sciences, Sacramento State College, Sacramento, California.

[2]Department of Entomology, University of California, Davis, California.

Materials and Methods

Studies were conducted in several rice fields west of Yuba City in Sutter County, California. Dipping and aquatic light trap collections of aquatic organisms were made weekly from six stations in 1966 and seven stations in 1969. The gut content of each *H. triangularis* larva was removed and stored in 70% ethyl alcohol and identifications of the organisms found in the digestive tract were made at a later date.

Adults in 10 gallon aquaria and artificial outdoor ponds (5′ x 5′) were observed to determine various aspects of their reproduction and environmental tolerances.

Results and Discussion

Adult females produced from one to fourteen egg cases in the laboratory at 72° F, and one to ten cases in the outdoor ponds. Hatching time for the eggs was three to seven days, averaging 3.5 days. The number of larvae produced per egg case ranged from 50 to 105 with the average being 83.5. The duration of the three larval stages varied considerably; the third stage persisted the longest. Pupation took place in underground chambers constructed by the larvae in wet soil, and lasted from 37 to 52 days in the laboratory.

Adults in aquaria and outdoor ponds fed largely on fila-

Table 1. Summary of Food Items in the Alimentary Tract of *Hydrophilus triangularis* Larvae in 1966 (454) and 1969 (332).

Food Item	Food Items per Beetle larvae x 100 1966	1969
Crustacea - Cladocera	0.22	5.42
Ostracoda - Podocopa	24.00	305.12
Insecta - Odonata (Anisoptera)	0.00	1.20
Hemiptera - *Belostoma* sp.	1.10	2.10
Corixidae	4.18	89.75
Coleoptera - *Tropisternus lateralis* (larva)	22.90	29.51
Laccophilus sp. (larva)	1.98	36.74
Thermonectus sp. (larva)	1.32	12.65
Hygrotus sp. (larva)	0.22	10.54
Misc.	0.66	17.46
Diptera - Chironomidae (larva-pupa)	39.86	215.06
Chironomidae (adult)	0.00	770.78
Stratiomyiidae (larva)	0.22	0.00
Tipulidae (larva)	0.22	0.60
Ceratopogonidae (larva)	1.76	0.00
Culex tarsalis (larva)	2.20	0.00
Miscellaneous	12.77	16.56

mentous algae and detritus. Adults reared in outdoor ponds and confined to cages in the water were able to withstand temperatures ranging from 34°F to 100°F. A number of adults were kept in cages in the water from July (1969) to February (1970) which indicates that overwintering of the natural population is possible in the adult stage.

A total of 786 larvae were dissected and gut content examined (Table 1). Midge larvae (Chironomidae) and seed shrimps (Ostracoda) were the most common organisms found in the gut contents of larvae collected during the study. The large number of adult midges recorded in 1969 was primarily a result of large numbers taken from a few individuals. The number of *Culex tarsalis* Coq. larvae (12) found in 1966 was low and absent in 1969. *Anopheles freeborni* Aitken larvae were not recovered in either year.

Predation of *C. tarsalis* by *H. triangularis* was greatest during the last week in May and the first three weeks in June. However, *C. tarsalis* did not become abundant in rice fields until July and August, the time when the lowest seasonal levels of *H. triangularis* occur.

In 1969 the field population of *H. triangularis*, *C. tarsalis*, and *A. freeborni* were all high from the first week in June through the first week in July. However, no mosquitoes were found in any of the beetle larvae collected during the year. For most other prey readily taken by the larvae, there appeared to be a direct correlation between those aquatic organisms available and those fed upon.

The following assessments of this beetle as a predator can be made based on observation and experimentation. *H. triangularis* has a relatively high fecundity and can withstand a wide range of climatic and environmental conditions. Factors hindering this beetle from becoming an effective predator of mosquitoes are: lack of specificity in feeding, short duration in the predator stage (larval stage), and peak seasonal distribution not coinciding with the peak abundance of the target organism.

A more complete evaluation on predation based primarily on forage ratio analysis will be reported on at a later date.

In summary, the alimentary tracts of 786 *H. triangularis* larvae from rice fields were examined. In 1966 midges (Chironomidae), seed shrimps (Ostracoda) and the beetle larvae of *Tropisternus lateralis* were fed upon most frequently. In 1969 Chrionomidae midges, Ostracoda, Corixidea, *Laccophilus*, and *T. lateralis* were most abundant in the gut contents. Mosquitoes constituted a very minor portion of the food items taken. Twelve *C. tarsalis* (larvae-pupae) were found in the gut contents of the beetle larvae sampled in 1966 and none in the larvae from 1969. A tentative conclusion pending further research is that *H. triangularis* appears to be opportunistic in its feeding habits. The feeding pattern, the limited abundance, and seasonal distribution in rice fields indicate that, at best, this species would not be a primary factor in controlling mosquitoes.

References Cited

Clarke, J.L. 1938. Mosquito control as related to marsh conservation. Proc. New Jersey Mosq. Ext. Assoc. 25:139-146.

Garman, W.H. 1881. The egg case and larvae of *Hydrophilus triangularis* Say. Amer. Natur. 15:660-663.

Matheson, R. 1914. Notes on *Hydrophilus triangularis* Say. Can Ent. 46:337-343.

Riley, C.V. 1881. Notes on *Hydrophilus triangularis* Say. Amer. Natur. 15:814-817.

Saunders, W. 1879. Entomology for beginners. Can. Ent. 11:221-223.

Wilson, C.B. 1923. Life history of the scavenger water beetle, *Hydrous (Hydrophilus) triangularis* and its economic relation to fish breeding. Bull. U.S. Bur. Fish. 39:9-38.

PARITY OF FALL–WINTER POPULATIONS OF *ANOPHELES FREEBORNI* IN THE SACRAMENTO VALLEY, CALIFORNIA

A PRELIMINARY REPORT

R. J. McKenna and R. K. Washino
Department of Entomology, University of California, Davis

Previous studies on overwintering *Anopheles freeborni* Aitken (Freeborn 1932; Washino 1970) indicated that females from these populations exhibited certain physiological changes in the fall of the year. These changes included a markedly reduced biting activity, the development of extensive fat body, and a reproductive diapause.

To extend these observations, age-determination studies were initiated with two specific objectives in mind. The primary objective was to determine more precisely if the overwintering female population was composed of nulliparous individuals as suggested earlier (Washino 1970). Of major concern was the determination of whether or not the blood feeding and non-blood feeding segment of the overwintering population diffeied in their physiological age. The second objective was to determine the parity in the gonoactive female population as a basis for later studies on longevity. This report is intended to summarize briefly the preliminary findings on these two objectives.

For the purpose of this study, parity was defined as the level of reproductive maturity an individual female has achieved expressed in terms of the number of gonotrophic cycles completed. For example, a nulliparous female has not undergone any gonotrophic cycles, while a uniparous has undergone one, a biparous two, etc.

Materials and Methods

Starting in August 1969, adult mosquitoes were collected once a week from three different locations west of Yuba City in Sutter County, California. These collection sites were as follows: Kroze, a farm house porch in an area of dense rice cultivation; DeWitt, a farm house porch approximately 1.5 miles away from Kroze and an area of dense rice cultivation; and Tarke, a bridge about 6 miles away from Kroze and an area of dense rice cultivation.

After collection, the mosquitoes were returned to the laboratory, anesthesized with chloroform, and the females separated into categories of empty (no blood or maturing eggs), blood engorged or gravid. When the abundance of mosquitoes permitted, a sample (10 to 15) of both the empty and blooded females was dissected from each of the three collection sites. The ovaries were examined at 50X and classified according to Polovodova's technique (Detinova 1962) of using the number of dilatations on the pedicels as an indicator of the number of gonotrophic cycles.

Giglioli's (1963) modification of the dissection medium was employed, using crystal violet dissolved in a relatively concentrated saline solution (rather than physiological saline). The advantage of the dye is obvious; the concentrated saline was beneficial since it caused the pedicels to remain stretched once manipulated into this position. To allow freedom of both hands and to facilitate dissections, a foot-operated focusing device (Strong 1969) was used after the third month of study.

In preparation for this study, approximately a month was spent by one of the authors (RJM) learning the technique with known material. This preparation culminated in scoring of 33 of 34 correctly in an examination of unknown mulliparous and parous individuals prepared by the other author (RKW).

Results and Discussion

A total of 7,839 female *A. freeborni* was collected from the three sites from August 13, 1969 until January 24, 1970. The proportion of females found empty, blood engorged or gravid and the parity of 917 individuals are summarized in Table 1. It appears likely that winter survival of *A. freeborni* in the Sacramento Valley is dependent on nulliparous and parous individuals prepared by the other November and December was encountered during the first week of November. These results agree with those of Nelson (1964) with *Culex tarsalis* Coq. and of Hitchcock (1968) with *Anopheles quadrimaculatus* Say. The condition of the females (i.e., nulliparity and stage I – II oocytes) seems to be consistent with the overwintering scheme suggested for *A. quadrimaculatus* (see p. 132, Hitchcock 1968).

From October until mid-January, all of the blood engorged females (37) were nulliparous and had their oocytes in stage I – II. It is suggested that these females were exhibiting gonotrophic dissociation since their oocytes were in stage I – II even in individuals with old blood. We also

Table 1. Percent blooded and parous *Anopheles freeborni* females collected from three sites in Sutter County, California, August through January, 1969-1970.

Month	No. females collected	% blooded	No. females examined	% parous
August	909	29.04	180	24.44
September	1541	5.38	248	25.00
October	2087	.81	187	1.60
November	1395	.78	135	.74
December	909	.33	94	.00
January	998	1.60	73	.00

concluded from these results that the occasional blood feeders that one finds during the winter months are from the same population as the non-blood feeders since both groups were nulliparous and with oocytes in stage I – II.

The oldest gonoactive females, found during the months of August, September and October, were biparous. A total of 14 such individuals was recorded (11% of the total parous females for these months). These results suggested that during the months the study was conducted, *A. freeborni* is not a long-lived mosquito. However, nine of these 14 females were blood engorged when collected, indicating that their third cycle had already been initiated. Therefore, females undergoing three or more gonotrophic cycles may occur, but perhaps much larger samples are needed to detect them.

Summary and Conclusion

The parity of 917 individuals was determined from females collected in Sutter County, California, from August 1969 through January 1970. It appears likely that the females overwinter in the nulliparous state. No difference in parity was observed between blood feeding and non-blood feeding individuals in the fall-winter population. Gonoactive females do not appear to be long-lived since the oldest individuals during late summer-fall were beginning only their third cycle.

References Cited

Detinova, T.S. 1962. Age-grouping methods in Diptera of medical importance; with special reference to some vectors of malaria. Wld. Hlth. Org., Monogr. Ser. 47, pp. 1-216.

Freeborn, S.B. 1932. The seasonal life history of *Anopheles maculipennis* with reference to humidity requirements and "hibernation". Amer. J. Hyg. 16:215-223.

Giglioli, M.E.C. 1963. Aides to ovarian dissection for age-determination in mosquitoes. Mosq. News 23:156-159.

Hitchcock, J.C. 1968. Age composition of a natural population of *Anopheles quadrimaculatus* Say in Maryland, U.S.A. J. Med. Entomol. 5:125-134.

Nelson, R.L. 1964. Parity in winter populations of *Culex tarsalis* Coquillett in Kern County, California. Amer. J. Hyg. 80: 242-253.

Strong, F.E. 1969. An inexpensive electric motor device for focusing stereoscopic microscopes by foot. Turtox News 47:274-275.

Washino, R.K. 1970. Physiological condition of overwintering female *Anopheles freeborni* in California. Ann. Entomol. Soc. Amer. 63:210-216.

FURTHER BIOLOGICAL AND CHEMICAL STUDIES ON *GAMBUSIA AFFINIS* (BAIRD AND GIRARD) IN CALIFORNIA

W. Ahmed, R. K. Washino and P. A. Gieke
Department of Entomology, University of California, Davis

With the increasing mosquito resistance to organophosphorous compounds and the general awareness of people of the disadvantages of pesticides in their environment, greater reliance may be placed on existing biological means of mosquito control. *Gambusia affinis* is used in some California rice fields for the biological control of larvae of *Culex tarsalis* and *Anopheles freeborni.* The feeding pattern of this fish in California rice fields has been the subject of study during the past three years. Results of this study suggest that effective mosquito larvae control by fish may be dependent on the availability of other food animals. To pursue this question, the feeding pattern of *G. affinis* was studied in 1969 in rice fields where mosquito reduction was and was not being achieved with the use of fish. A second phase of this study investigated the susceptibility of *G. affinis* to commonly used insecticides. This information is essential in integrating the biological and chemical mosquito control program. This is a progress report that summarizes preliminary results of the two investigations, and outlines plans for future studies.

Procedure

The variations in the feeding patterns of *G. affinis* in several rice fields were studied in Yolo County with the cooperation of the Sacramento Co. – Yolo Co. Mosquito Abatement District. Each field showed different levels of mosquito abundance. One field (R8) showed satisfactory mosquito control presumably being achieved by the fish. A second field (75A), stocked with fish, had a sufficient number of mosquito larvae to necessitate an insecticide application. A third field (75B), also stocked with fish, appeared to have satisfactory mosquito control on one side of the field (west) but not on the opposite side (east). Approximately 150-200 fish were collected during the third and fourth week of August from different stations of each field (a total of 699 fish). The fish were killed instantly after collection, brought to the laboratory and stored in 70% ethyl alcohol until examined. Gut content of the fish was examined under a dissecting microscope at 40X. Estimations of the mosquito populations in all fields under study were made by Sacramento Co. – Yolo Co. MAD on the basis of dipping samples.

The susceptibility of *G. affinis* to different insecticides was determined on fish obtained from the Sutter-Yuba MAD. Fish used for the tests were kept for 24 hours in the laboratory before being exposed to the insecticide. Dilutions of the stock solution of insecticides were made using re-distilled acetone. Ten unsexed fish were transferred with a strainer into gallon, glass jars containing 1000 ml of aged tap water. Three replications were taken for each concentration. An equivalent amount of acetone was added to the control. Mortality was recorded every six hours up to 72 hours. The test material was also checked with a susceptible strain of *Culex pipiens*. Temperature range during the test was 72 ± 2°F.

Results and Discussion

Results of the gut analysis (Table 1) confirm results of earlier studies in that crustaceans and chironomid midges appeared to be the major food items of *G. affinis* in rice fields. The greater feeding on the *Anopheles* rather than on *Culex* can probably be attributed to the period of sampling rather than a preference for one mosquito over another. Fish samples were collected in late August when anophelines are normally at peak numbers and well past the usual peak period for *C. tarsalis* in rice fields.

If a comparison is made between the feeding pattern of fish from fields with and without a heavy mosquito population, the major difference appears to be the feeding on crustaceans. Feeding on anophelines is the same in Field R8 (which had little or no mosquitoes) and Field 75A

Table 1. Comparative feeding pattern of *Gambusia affinis* (food item per fish) in four rice fields in Yolo County, California, 1969.

	Food item per fish			
Food Organisms	Field R8	Field 75A	Field 75B (west)	Field 75B (east)
Anopheles sp.	0.56	0.56	0.02	0.29
Culex sp.	0.07	0.00	0.00	0.00
Chironomidae larvae	5.00	3.92	1.94	0.46
adults	0.59	0.42	0.40	0.23
pupae	0.56	4.88	0.08	0.00
Crustacea	11.63	28.08	6.08	37.23
Aphidae	0.03	0.70	0.60	0.00
Thysanoptera	0.01	0.16	0.31	0.34
Tipulidae	0.13	0.01	0.00	0.00
Hygrotus sp.	0.19	0.01	0.03	0.00
Corixidae	0.10	0.18	0.14	0.04
Dytiscidae	0.05	0.10	0.03	0.00
Collembola	0.10	0.07	0.01	3.33
Thermonectus sp.	0.04	0.00	0.00	0.00
Odonata	0.01	0.02	0.01	0.02
Belastoma sp.	0.01	0.00	0.00	0.00
Tropisternus sp.	0.00	0.08	0.02	0.01
Others	0.16	0.10	0.10	0.18

(which had many mosquitoes), but feeding on the crustaceans was considerably greater in the field which had many mosquitoes. A somewhat similar relationship was observed in Field 75B (east and west). These results suggest that crustaceans may be a critical food item that affects the level of fish-mosquito interaction in the rice fields. Further analysis (i.e., forage ratio) is necessary to confirm these observations.

The study of susceptibility of fish to pesticides was limited to parathion and methyl parathion. The mosquito fish showed no mortality when exposed to a maximum concentration of 6.0 ppm of methyl parathion in 72 hours. In a 24-hour test, the fish showed a mortality range from 0 at 0.05 ppm to 100% at 0.3 ppm of parathion. Mortality of *Culex pipiens* (laboratory strain) in bioassay confirmed insecticidal activity of test chemicals.

Lewallen (1950) observed an average fish mortality of 33% in the laboratory tests of field-collected *G. affinis* at the dosage of 0.004 ppm parathion. Mulla (1961) reported 30% mortality in the field trials with parathion at the rate of 0.1 lb per acre. Roberts (1964) reported LC_{50} values ranging from 0.03 to 0.05 ppm for methyl parathion against four different populations of *G. affinis* from Mississippi. For speculative reasons, if our results are compared with those of Lewallen (*ibid.*), Mulla (*ibid.*)[1] and Roberts (*ibid.*), fish in our study showed moderate tolerance to parathion, and considerable tolerance to methyl parathion.

This is especially interesting in the light of studies in Mississippi where workers have reported development of resistance by *G. affinis* to parathion (Ferguson and Boyd 1964; Burke and Ferguson 1969) and Dursban (Ferguson et al. 1966). The relationship of *Gambusia* to insecticides used to control mosquitoes in California is not clear, and obviously requires considerably more work than described here. It is too early to attribute the high tolerance levels observed in this test to resistance, but it is interesting to speculate on the use of resistant fish in biological-chemical control programs in rice fields. It would be a distinct advantage to have fish withstanding the application of mosquito larvicides with a minimum mortality. On the other hand, with chlorinated hydrocarbons and other stable chemicals, it is possible that resistant *G. affinis* with chemicals in them may result in certain ecological consequences. They may find their way into rivers and could effect game fish and possibly even man. Our present work plans call for testing populations of *G. affinis* from different areas to establish if susceptibility to organophosphate insecticides used for mosquito control varies with locality.

[1]Assumption is made that at depths of approximately 4 in, 1 lb active material/acre will be nearly equal to 1 ppm.

References Cited

Burke, W.D., and D.E. Ferguson. 1969. Toxicities of four insecticides to resistant and susceptible mosquitofish in static and flowing solutions. Mosq. News 29:96-101.

Ferguson, D.E. 1968. Characteristics and significance of resistance to insecticides in fishes. Reservoir Fishery Resources Symposium, Athens, Georgia. p. 531-536.

Ferguson, D.E. and C.E. Boyd. 1964. Apparent resistance to methyl parathion in mosquitofish, *Gambusia affinis*. Copeia 1964: 706.

Ferguson, D.E., D.T. Gardner, and A.L. Lindley. 1966. Toxicity of Dursban to three species of fish. Mosq. News 26:80-82.

Lewallen, L.L. 1959. Toxicity of several organophosphorous insecticides to *Gambusia affinis* (Baird and Girard) in laboratory test. Mosq. News 19:1-2.

Mulla, M.S. 1961. Fields studies on the toxicity of insecticides to mosquito-fish *Gambusia affinis*. J. Econ. Entomol. 54:1237-1242.

Roberts, M.D. 1964. Some studies on resistant and non-resistant mosquito fish (*Gambusia affinis* Baird and Girard). M.S. Thesis. Mississippi State University 25 p.

MOSQUITOES ON THE OFFSHORE ISLANDS IN CALIFORNIA

Richard D. Spadoni[1] and Richard O. Hayes[2]

Abstract

From November 1967 to May 1969, Public Health Service entomologists in Bakersfield, California, made a part-time study of mosquitoes on the Channel Islands of California. The purpose was to determine what species were present and whether they were likely to pose public health problems.

The islands range from 12 to 55 miles off the mainland from San Diego on the south to Point Conception on the north. Those surveyed were San Clemente and Santa Catalina in Los Angeles County, San Nicolas and the Anacapas in Ventura County, and Santa Rosa and Santa Cruz in Santa Barbara County. Also, a survey was made on South Farallon Island, some 25 miles west of San Francisco.

Two general types of habitat are represented on these islands: a grazing-land habitat and a barren-land habitat. Ten mosquito species were found on the grazing-land islands (Santa Catalina, Santa Cruz, and Santa Rosa) these were *Aedes sierrensis* (Ludlow), *Aedes squamiger* (Coq.), *Culex apicalis* Adams, *Culex peus* Speiser, *Culex erythrothorax* Dyar, *Culex pipiens quinquefasciatus* Say, *Culex tarsalis* Coquillett, *Culiseta incidens* (Thomson), *Culiseta inornata* (Williston), and *Anopheles pseudopunctipennis franciscanus* McCracken. Three species, *C. incidens*, *C. inornata*, and *C. tarsalis*, were found on the barren-land islands (the Anacapas, San Nicolas, San Clemente, and South Farallon). However, it was concluded that mosquitoes probably would not normally cause significant public health problems on these offshore islands.

[1]Disease Ecology Section N.C.D.C., U.S.P.H.S., Oroville, California.

[2]Disease Ecology Section N.C.D.C., U.S.P.H.S., Fort Collins, Colorado.

ARBOVIRUS RESEARCH IN THE SACRAMENTO VALLEY[1]

R. L. Nelson
Arbovirus Field Station, School of Public Health
University of California, Berkeley

In the spring of 1969, a research on arboviruses was begun in the Sacramento Valley. This is an area where both western equine encephalomyelitis (WEE) and St. Louis encephalitis (SLE) have been a continuing problem and where field studies of arboviruses have been largely neglected. The new studies are an extension of research pursued for more than 20 years in Kern County and involved the transfer of some personnel and equipment from the Arbovirus Field Station in Kern County. The original intent was to begin the project in September, 1969, with a supporting 5-year federal grant; however, a supplemental grant from the University of California (Berkeley) and an offer of temporary work space by the Butte County Mosquito Abatement District permitted the program to begin 6 months ahead of schedule.

The initial permanent staff consisted of a zoologist and 2 entomologists, representing the University's School of Public Health and the National Communicable Disease Center of the U.S. Public Health Service. The staff is currently being increased by the addition of a zoologist and a technician. By the end of February, 1970, the station will be transferred from the offices of the Butte County district in Oroville to permanent quarters near Chico.

The project has received strong support from a number of mosquito abatement districts, but particularly from the Butte and Glenn County districts where the studies are centered. In addition to work space, the Butte County district has provided a full-time summer assistant who is a graduate student in biology at Chico State College. Both districts have helped extensively with the establishment of study sites and by operating mosquito light traps near the sites.

Before briefly describing the first summer's activities, it may be of interest to review information available on arboviruses in Butte and Glenn Counties. Table 1 lists laboratory-confirmed cases of encephalitis in man and horses from 1952 through 1969. In this period, there were 16 cases of WEE and 28 of SLE in man. As in much of the Central Valley of California, there were more cases of WEE in 1952 and more of SLE in 1954 than in any of the other years. Records of WEE in horses are lacking prior to 1961, but 27 cases have been recorded in the past 10 years, including 11 in 1964.

In recent years, various county health departments have submitted tree and ground squirrels to the laboratories of the California State Department of Public Health to be tested for rabies. It is of considerable interest that WEE virus has frequently been isolated from the brains of these squirrels (Lennette et al. 1956; Dr. R.W. Emmons, Personal communication 1969). Of 28 isolates from Northern California, 15 were from Butte County. This clearly indicates that WEE virus is infecting squirrels in Butte County. In addition, the same virus was isolated from the brain of an opossum captured in Butte County in 1968 (Emmons and Lennette 1969).

Finally, tests for antibodies in blood sera taken from domestic chickens in Butte and Glenn Counties in the fall of 1968 showed that WEE, SLE, and Turlock viruses were active in both counties.

In April, 1969, when studies began, 12 study sites were established in the 2 counties. They range from Paradise in the northeast, at an elevation near 2,000 feet, to the Sacramento National Wildlife Refuge in the southwest, which is on the valley floor. Some are within mosquito abatement districts and others are not. Both urban and rural areas, including rice and orchard land, are represented.

At each of the sites, a sentinel chicken flock was set out and mosquitoes were collected weekly. The chickens were bled at monthly intervals from May through November and their sera were tested for antibodies. Mosquitoes were collected by light traps to measure population fluctuations and by bait traps for virus tests. Bait traps were baited either with dry ice or with 3-week-old chickens. Blood and serum samples were taken from the chickens after their exposure to obtain a measure of virus transmission rates. Also, beginning in August, weekly collections were made of mosquitoes in shelters to obtain additional specimens for virus and blood-meal-identification tests.

Birds and mammals were trapped in several areas of the 2 counties to obtain base line data on the involvement of wild birds and mammals with viruses. The usual procedure was to band, bleed, and release captured animals and to test their sera for antibodies. To supplement this study, arrangements were made to collect serum samples from birds and mammals at the Sierra Foothills Range Field Station in Yuba County. Also, the Tehama County Mosquito Abatement District arranged for a series of bleedings on exotic birds raised in Tehama County.

Laboratory tests of blood samples and mosquitoes are incomplete, but results of tests completed showed a late-season flurry of SLE virus activity. There were 2 cases of St. Louis encephalitis in man in Glenn County (Table 1), and 21 of 188 sentinel chickens showed evidence of exposure to SLE virus. Twelve isolations of SLE virus were made from nearly 15,000 *Culex tarsalis* Coq. It is of interest that 8 isolations were from specimens collected within 1 mile of the Sacramento River. One suspected case of WEE in a horse and a single sentinel chicken with antibodies to WEE virus were the only indications of WEE virus activity. However, about 40,000 additional mosquitoes, including more than 9,000 *C. tarsalis* and 25,000 *Anopheles freeborni* Aitken, remain to be tested.

It is anticipated that the Sacramento Valley project will continue for a minimum of 5 years, with studies being ex-

[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-S01-FR 05441 from the National Institutes of Health, U.S. Department of Health, Education, and Welfare.

Table 1. Confirmed cases of human and equine encephalitis in Butte and Glenn Counties (California,) 1952-1969.[a]

	Butte County			Glenn County		
	Human		Equine	Human		Equine
	SLE	WEE	WEE	SLE	WEE	WEE
1952-1959	16	9		3		
1960						
1961			1			
1962	3		2			3
1963						
1964		1	10			1
1965			2	1		
1966			2			
1967	2	3	5	1	2	
1968		1	1			
1969				2		

[a] Data supplied by the California State Department of Public Health, Berkeley, California.

panded. In 1970, 3 additional study sites will be established near the Sacramento River. Already started is a study of autogeny in *C. tarsalis*. The overall objective is to determine the realtionship, if any, of autogeny to the capacity of *C. tarsalis* as a vector. Another study will investigate the possible role of other mosquito species, including *Aedes sierrensis* (Ludlow), as vectors of viruses. Because of the interest in squirrels, a zoologic study of activity patterns and ectoparasite infestations of tree and ground squirrels is now beginning. Efforts also will be made in 1970 to learn what species of *Culicoides* midges are present in the Sacramento Valley study areas, and if they are involved with viruses.

Hopefully, these and other contemplated studies will contribute to an understanding of encephalitis in the Sacramento Valley, and will assist local health and mosquito abatement personnel in their efforts to protect the public from encephalitis.

References Cited

Emmons, R.W., and E.H. Lennette. 1969. Isolation of western equine encephalomyelitis virus from an opossum. Science 163:945-946.

Lennette, E.H., M.I. Ota, M.E. Dobbs, and A.S. Browne. 1956. Isolation of western equine encephalomyelitis virus from naturally-infected squirrels in California. Amer. J. Hyg. 64:276-280.

FLIT MLO PREFERRED FOR MOSQUITO CONTROL IN RESIDENTIAL AREAS

Jack H. Kimball
Orange County Mosquito Abatement District, Santa Ana

FLIT® MLO has effectively and economically controlled mosquito production for a 14 day period when applied at the rate of 2 to 3 gallons per acre to breeding sources associated with urban community drainage facilities in Orange County. Because of its proven effectiveness on an operational basis over 32 sq miles of urban area, the use of FLIT MLO will be extended to the entire 320 sq miles of urban community area within the District for the forthcoming 1970 season. The use of FLIT MLO is preferred over conventional pesticides for the following reasons.

1. The use of FLIT MLO eliminates any hazard to the general public as well as to fish and wildlife.
2. The use of FLIT MLO eliminates any hazard to District employees.
3. The use of FLIT MLO reduces the spray route man hours and vehicle mileage up to 50% by increasing to 14 days the 7 day spray cycle required for emulsions or granular type larvicides.

FLIT MLO was first used during the 1968 season in a ten square mile urban area in northern Orange County. From an operational standpoint, we found the results satisfactory.

FLIT MLO was tested again in northern Orange County during the 1969 season. Testing was done in a 32 square mile area or 1/10 of the total urban area in the District. Regular treatment cycles were begun on June 1, 1969, and ended on October 19, 1969. A time lapse of 14 days was maintained in all areas for the full summer season. The six incorporated cities encompassed within this test area have a total population of 120,000 and are located on rolling foothills at an average elevation of 350 ft. The average mean temperature for the test area was 72°F with maximums in the nineties and minimums in the fifties during the summer season.

The number and major types of community drainage facilities within the 32 sq mile test area which are chronic mosquito breeding sources are as follows:

Curb Inlets	–	790 sites
Street gutters	–	25 sites totaling 30,280 ft
Roadside ditches	–	53 sites totaling 59,600 ft
Off streat drains	–	10 sites totaling 14,400 ft

FLIT MLO was applied to all breeding sites located on public rights-of-way from an International Harvester Scout equipped with a 50 gallon pressure tank maintaining a 40 psi at the nozzle.

An application rate of from two to three gallons of FLIT MLO per acre to street gutters and roadside ditches was obtained by using a Spraying Systems Adjustable Cone Jet nozzle No. 5500-X3 set at its minimum discharge rate of 0.05 gpm and by driving at a speed of five mph. The nozzle was adjusted to its maximum setting of 0.20 gpm to produce a jet stream pattern for "slugging" in curb inlets to underground storm sewers as well as for reaching occasional sources located 10 to 15 ft from the vehicle. For off-street application, FLIT MLO was applied by a two-gallon hand spray can using the same pressure and nozzle.

Of the four separate community drainage routes within the test area, three were treated eight times and one was treated nine times for a total of 33 treatments during the full season. A total of 364 gallons of FLIT MLO were used. The No. 5500-X3 Spraying Systems Cone Jet nozzle was found most satisfactory for this operation because the minimum spray setting produced a droplet size large enough to prevent drifting and swirling and the jet setting provided distance when needed.

During the 1969 season, random checks were made throughout the area. It was determined through these checks that by the 12th-13th day there was breeding in most areas but breeding was 90% larvae and 10% pupae. This would indicate that 14 days between treatment was not too long a period. Random checking after treatment with a time lapse of 24-48 hours showed 90-100% kill. There was no noticeable increase in emergence of adult mosquitoes and no increase in numbers of service requests from this test area.

A precise evaluation of the efficiency of FLIT MLO during one spray cycle was made by the District Vector Ecologist, Gilbert L. Challet for the period of September 2, 1969 through September 17, 1969. The sequence consisted of pre-spray qualitative and quantitative sampling, actual spraying, 24-hour post-spray sampling and a 13-day post-spray sampling. Table 1 presents the effectiveness of FLIT MLO in the control of the three species of mosquitoes found in seven typical breeding sources within the test areas. The conclusions of this evaluation were (1) that FLIT MLO kills both larvae and pupae when applied at the rate of from two to three gallons per acre, and (2) that FLIT MLO provides control for a period of up to 14 days in Orange County.

The use of FLIT MLO is economical because the dosage rate in gallons per acre is the same as required for diesel oil fortified with a suitable pesticide. The elimination of the pesticide for the control of mosquito breeding in community drainage facilities accessible to the general public is the objective of the Orange County Mosquito Abatement Distirct. The quantity of FLIT MLO required to maintain satisfactory mosquito control for a 14-day period within the 32 sq mile test area averaged 1.4 gallons per square mile. The spray operators time averaged 1.1 hours per square mile.

The use of FLIT MLO at the rate of 2 to 3 gallons per acre on a 14-day treatment cycle throughout our 320 sq miles of urban area has been adopted for the 1970 season because its use eliminates any hazard to the general public and to the District spray operator as well as to fish and wildlife.

The use of FLIT MLO will expand up to 50% the urban area which each spray operator can service.

Table 1. Evaluation of FLIT MLO for mosquito control in residential areas.

Source Location			Pre-Treatment Inspection Sept. 2, 1969			24 hr. Post-Treatment Inspection Sept. 3, 1969		13-day Post-Treatment Inspection Sept. 15, 1969		
			No. per dip			No. per dip		Number per dip		
No.	Map and Section	Source Description	(by instar)	pupae	Species Present	larva	pupa	larvae (by instar)	pupae	Species Present
1	4-26	Roadside ditch	0	2	*Culex quinq.*	source	day	4 (All)	1	*Culex quinq.*
2	4-35	Paved gutter	9 (2,3,4)	1	*Culex quinq.*	0*	0	0	0	–
3	4-25	Roadside ditch	4 (All)	1	*Culex quinq.*	0	0**	0	0	–
4	1W-6	Offstreet drain	4 (2;3,4)	1	*C. quinq., C. peus, Culiseta incidens*	0	0	10 (All)	0	*Culex peus*
5	1W-6	Natural drain	4 (3,4)	1	*Culex quinq.*	0	0	30 (All)	0	*Culex quinq.* *Culex peus*
6	1W-4	Natural drain	16 (3,4)	4	*Culex quinq.*	0	0	19 (2,3,4)	1	*Culex peus*
7	1W-9	Natural drain	20 (3,4)	10	*Culex quinq.* *Culex peus*	0	0	20 (All)	0	*Culex quinq.*

Sprayed under routine operational conditions at an average rate of 2 gals per acre. The mean temperature for this period was 72°F with a maximum of 92°F and a minimum of 56°F.

* several dead larvae present
** several dead pupae present

BUFFALO GNAT (SIMULIIDAE) CONTROL IN THE SOUTHEAST MOSQUITO ABATEMENT DISTRICT

Frank W. Pelsue[1], Gardner C. Mc Farland[1], and Harvey I. Magy[2]

In recent years, the Southeast Mosquito Abatement District has been called upon to control "buffalo gnats" (Simuliidae) that have been bothering residents living adjacent to the Big Tujunga Wash areas of the City of Los Angeles. This natural river has its origin in the San Gabriel Mountains and empties into the Hansen Dam basin. With the increased rainfall beginning in 1967 and climaxing in 1969, several species of the family Simuliidae had built up to nuisance numbers. In 1968 a moderate adult and larval population occurred with adults occasionally biting local residents, but no chemical control was effected at that time. However, in 1969 a tremendous larval population occurred with some adults emerging in early spring and annoying residents. At this time, it became apparent that some level of control would have to be effected, based on the extent and density of the larval population.

The Los Angeles County Flood Control District has control of the water in the Big Tujunga Wash area, so they contacted the Southeast MAD after receiving complaints from local residents. The Southeast MAD was asked to survey the problem area and recommend possible control measures. After surveying the problem, it was determined that immediate chemical control measures were necessary. In conformance with our contract with the L.A. County Flood Control District, control measures were undertaken.

This paper is a preliminary report on the results of the control measures effected against the various simuliid species encountered in Big Tujunga Canyon area.

Over the years, the control of buffalo gnat larvae has been accomplished using DDT at various concentrations in many areas of the world. Fairchild and Barreda (1945) obtained complete control at distances up to 10 kilometers with a concentration of 1 ppm for 60 minutes in Guatemala using DDT. In Kenya, Garnham and McMahon (1947) used DDT at 1 to 27 ppm to achieve complete larval elimination. Kindler and Regan (1949) reported larval control in New Hampshire using TDE at 1 ppm for 10 minutes over a 5-mile section, with the insecticide introduced at 1-mile intervals. Gjullin et al. (1949) studied the effectiveness of several insecticides on larvae and found DDT to be the most effective for distances up to 880 yards at a concentration of 0.3 ppm after 15-minute application periods. Davis et al. (1957) evaluated DDT, dieldrin, and parathion for simuliid control in Florida and South Carolina. They found that parathion at dosages of 0.5 and 1 ppm gave good control in slow moving streams with distances up to 2.3 miles. They also found that 5% DDT in fuel oil applied by aircraft at 2 quarts per acre gave from 95-99% control for 2 weeks. In aerial applications of Dieldrin granules at the rate of 0.04 pounds per acre, larvae were eliminated for 2 weeks with above 90% control accomplished through 4 weeks.

Jamnback (1962) screened black fly larvae against a variety of insecticides, finding that of the insecticides tested, fenthion gave the best control at concentrations of 0.33 – 3.33 ppm. Frempong-Boadu (1966) tested methoxychlor, fenthion and carbaryl against several species of Simumdae larvae and found that methoxychlor was slightly superior to fenthion and carbaryl using, as a criteria, the concentration of insecticide which caused 50% of the larvae to detach. Concentrations used in this experiment ranged from 0.1 – 4.0 ppm depending on the material.

From a review of the literature, one can conclude that several insecticides are effective in controlling simuliid larvae at concentrations ranging from 0.1 – 27 ppm.

The choice of insecticide should depend on the following factors: effectiveness against buffalo gnat larvae, low toxicity to vertebrates, selectivity (effects on nontarget organisms), lack of long-term persistence so as to avoid buildup in the ecosystem, and cost (after WHO Tech. Report 335).

Materials and Methods

In this study, four species of buffalo gnats were found occurring in the Big Tujunga Wash area. In 1969, *Silulium argus* Williston, *S. vittatum* Zatterstedt, and *S. virgatum* Coquillett were collected; and in 1968 *S. tescorum* Stone and Boreham was taken. In 1969, we did not collect any *S. tescorum*; but we received several reports of gnats biting and as *S. tescorum* is a fierce biter of man it was probably also present along with the other three species.

In July, there were two streams in the Big Tujunga Wash area infested with *Simulium* sp.. These were the main streams (stream M) originating from the Big Tujunga Dam in the San Gabriel Mountains and the other was a small stream (stream Q) originating from fishing water in a rock quarry in the Hansen Dam basin. In addition, the Hansen Dam spillway was also infested, however, this was not found until August after we had treated the streams M and Q in July. In the spillway area, we had a tremendous adult emergence and reinfestation occurred at three-week intervals through the middle of October.

The insecticide chosen for treatment was Abate®, (0, 0, 0',0'-tetramethyl 0, 0'-thiodi-p-phenylene phosphorothioate.) This choice was based on Abate's low mammalian, avian and fish toxicity. Five quarts of Abate were diluted in 100 gallons of water. This was flowed into the stream for 60 minutes to achieve a final concentration of 0.5 ppm in stream M. Stream Q was treated at the same rate. The material was injected using a standard mosquito abatement air pressure sprayer equipment mounted on a jeep.

The area treated in stream M was approximately 5 miles in length, with two injection points, one at an arbitrary beginning well out of the residential area and the other at the midway point. There was 46 second feet (20,700 gallons/minute) coming down stream M, while stream Q had 12.3 second feet (5535 gallons/minute) and was treated at its head waters in the rock quarry. Treatment distance for Q was approximately one mile. The Hansen Dam spillway

[1]Southeast Mosquito Abatement District, South Gate.

[2]Bureau of Vector Control and Solid Waste Management, California State Department of Public Health, Los Angeles.

was treated by shutting off the water and treating the leakage (which was enough to keep the immatures attached) with Abate at the same dosage rate used in the stream treatments.

Population level in stream M was extremely high with every rock, aquatic plant, and bit of debris covered with larvae, averaging 10-20 larvae per square inch. In stream Q, the larval population was considerably lower averaging 2-8 per square inch of infested surface. In the Hansen Dam spillway, the population average was extremely high with an average count of 20-30 per square inch of infested surface. The adult average in the Hansen Dam spillway was approximately 5-10 per square inch in the shady areas (channel wall and flumes).

In the Hansen Dam spillway, the population seemed to consist of only *S. argus* and *S. vittatum*, while in the streams both of the above species were present in addition to *S. virgatum* in 1969. In 1968 *S. tescorum* was the only species collected; however, the other species were undoubtedly present.

Since the only large adult population was present in the Hansen Dam spillway and the only species apparently present in this area were *S. argus* and *S. vittatum*, we assume one of these species was biting. We base this assumption on the biting reports received from workers on a golf course adjacent to the dam spillway. In 1968, we know that *S. tescorum* was biting, as specimens were collected at the home of one of the complainants and gnats were observed biting.

Results and Discussion

Treatment sites were checked 24 hours after treatment and approximately 95% detachment had occurred, and those that remained attached were dead, giving us 100% kill following treatment in all areas treated. In the streams, only a small number of pupae were present at the time of treatment so a minimum number of adults emerged. Reinfestation did not occur as mud stirred up by sluicing activities in the Big Tujunga Dam made the water in the stream M uninhabitable for simuliid larvae. The sluicing activities were begun approximately one month after treatment, but weekly inspections, until that time, indicated that reinfestation had not occurred in stream M. In stream Q, reinfestation was first noticed in the first part of September and periodic inspections to date show the population at a relatively low level.

In the Hansen Dam spillway, reinfestation occurred about every three weeks due to the large adult population. This area was treated three times from early August through September. We also did some limited adulticiding, but this did not prevent reinfestation, as adults were continually emerging. In this area, 100% larval control was obtained; but the Abate did not seem to affect the pupae, probably due to the low insecticide concentration and short contact time.

We chose Abate over fenthion, primarily due to its low mammalian and avian toxicity particularly its lower toxicity to ducks. The Big Tujunga Wash empties into the Hansen Dam Reservoir, which has a large population of ducks and fish. After treatment we did not notice any change in the aquatic funa, so apparently Abate at the concentration used was harmless to nontarget organisms.

Approximately one hour after treatment, the gnat larvae began to behave abnormally detaching from their attachment sites and moving downstream on their silken threads, some being caught in the algae along the bank of the stream and dying there. After 24 hours rocks that were formally heavy with larvae were clean.

Due to the extent of the larval population and age of the larvae (75% were 4th instars) time of treatment was important so as to prevent a large number of adults from emerging. No time was taken to determine the least amount of material needed to achieve economical control of the simuliids. We hope in the coming season to do some definitive work on the use of Abate against simuliid larvae, determing the minimum concentration required to achieve 100% control

Summary and Conclusion

In controlling buffalo gnats in the Big Tujunga Wash of the City of Los Angeles, a relatively new organophosphate insecticide Abate® 4E was utilized. It was chosen over other materials because of its low mammalian, avian, and fish toxicity, and its relative short residual qualities.

Two streams and the Hansen Dam spillway were the sites of treatment. In all cases, 100% control of the larval form was obtained with an Abate concentration of 0.5 ppm injected using an air pressure type spray rig flowing the material into the stream for one hour allowing it to flow down the stream through the areas where larval control was desired.

Detachment of simuliid larvae was achieved in 24 hours. Reinfestations of the stream area occurred in 60 days. Reinfestation of the Hansen Dam spillway occurred in 15 days due to the large adult population which occurred here.

We feel that Abate provides suitable control of buffalo gnat larvae while apparently not affecting nontarget organisms. However, we also feel further research should be done to determine the minimum concentration at which 100% control could be achieved, and to document which species were actually biting.

Acknowledgments

The authors would like to thank Jack Reinhard and A.A. Ingram of the Los Angeles County Flood Control District for their cooperation in this project; and we would also like to thank Gail Grodhaus, Associate Vector Control Specialist, California State Department of Public Health and Dr. Charles Hogue, Senior Curator of Entomology, Los Angeles County Museum of Natural History for making identifications of the simuliid species used in this study.

References Cited

Davis, A. Nelson, James B. Gahan, John A. Fluno, and Darrell W. Anthony. 1957. Larvicide tests against black flies in slow-moving streams. Mosquito News 17(4):261-265.

Fairchild, G.B., and E.A. Barreda. 1945. DDT as a larvicide against *Simulium*. J. Econ. Entomol. 38(6):694-699.

Frempong-Boadu, J. 1966. A laboratory study of the effectiveness of methoxychlor, fenthion, and carbaryl against blackfly larvae (Diptera: Simuliidae). Mosq. News 26(4):562-564.

Garnham, P.C.C., and J.P. McMahon. 1947. The eradication of *Simulium neavei* Roubaud from an Onchocerciasis area in Kenya colony. Bull. Entomol. Res. 37(4):619-628.

Gjullin, C.M., O.B. Cope, B.F. Quisenberry, and F.R. Duchanois.

1949. The effect of some insecticides on blackfly larvae in Alaskan streams. J. Econ. Entomol. 42(1):100-105.

Jamnback, Hugo. 1962. An electric method of testing the effectiveness of chemicals in killing blackfly larvae (Simuliidae: Diptera). Mosquito News 22(4):384-389.

Kindler, J.B., and F.R. Regan. 1949. Larvicide tests on blackflies in New Hampshire. Mosquito News 9(3):108-112.

World Health Organization. 1966. Expert committee on Onchocerciasis second report – Control of *Simulium* vector with adulticides and larvicides. WHO Tech. Rept. Ser. 335:71-78.

TULARE LAKE 1969 – DIARY OF A DISASTER

Richard F. Frolli
Kings Mosquito Abatement District, Hanford

California's Phantom Lake has returned. The Tulare Lake Basin was flooded in January 1969 by distributaries from the Kings, Kaweah and Kern rivers; Cross, Deer and White creeks. The floods were relentless, silent, and steady from January through June as they culminated in a lake covering 130 sections, holding one million acre feet of flood water. This lake will stand for 3 years, the last potholes drying up in the summer of 1971.

The waters of the lake have locked up the rich farm soils of the Basin, costing a crop loss of 25 million dollars each year to our community. Beneath the waters of the lake remain thirty-five miles of paved road systems. Replacements for these roads will cost 3½ million dollars. Everything else, the farms, canals, ditches and fields have been destroyed. It will be fall of 1971 before this area can be restored, cultivated and crops grown again.

I see the Tulare Lake a quiet lake, lapping gently at its shores, but like all lakes it has its moods. At times the Tulare Lake will roar, froth, and slash at its levees binding and restraining it from its ancestral boundaries which were 760 square miles. Sometimes its breakers will splash spray 20 feet in the air.

It will nurture bird life then inflict the stench of botulism upon 40,000 birds. It will invite hunters and fishermen to its bounty, then upset their boats in a jealous frenzy. In January of 1970 it took the lives of two boys.

Regarding mosquito activity during 1969 we at the Abatement District had plenty of time to prepare for the summer and we had the 1967 flood season to reflect upon. Our approach, therefore, was orderly, setting up for money, for men and for materials. It may be a mistake to equate orderliness with efficiency, but orderliness gives one a sense of confidence and we never worried that the situation would get the upper hand. To support our campaign we went about seeking money early. It came from a raise in District tax rate, from the Office of Emergency Preparedness, from the Navy, and from the Kings and Tulare counties' Boards of Supervisors. During the six month season, our expenditures reached $300,000 surpassing our normal twelve-month budget of $250,000.

Our normal complement of men is 23 during the summer months. We increased this by three men – two of those pilots, bringing their numbers to four. We purchased two additional aircraft for the season. During the normal day we would have 4 to 5 aircraft spraying; occassionally we would have as many as 6 in one day. Each aircraft was capable of treating 1000 acres per day; some missions were flown at night. This was all "on the deck" flying. Our basic larvicide for *Culex tarsalis* was methyl parathion and we treated 320,000 acres.

During the winter months control emphasis shifted to source reduction methods. Our source reduction people eliminate approximately 30 potholes, small lakes, and ponds each month as the waters recede. Mopping up will continue as the lake dries.

The phantom Tulare Lake holds a fascination to people who do not live in the area and they like to see it come. But those who are directly affected in the Tulare Lake Basin feel otherwise.

MOSQUITO VECTOR AND ARBOVIRAL SURVEILLANCE IN KERN COUNTY, 1969[1]

Richard N. Lyness
Arbovirus Field Station, Bakersfield

From April through October, 1969, observations were made on vector populations at 24 sites representing suburban, rural community and rural agricultural habitats in cooperation with the Kern Mosquito Abatement District.

[1]This investigation was supported in part by the National Institute of Allergy and Infectious Diseases Research Grant AI 03028, and General Research Support Grant I-S01-FR-05441 from the National Institutes of Health, U.S. Department of Health, Education and Welfare.

Viral activity was measured by immunologic conversion rates in 9 sentinel chicken flocks that were bled during the last week of each month from May through November.

Viral isolation attempts from *Culex tarsalis* included specimens taken in shelter at four locations, chick-baited traps at 24 locations in suburban, rural community and rural agricultural habitats, and a small number of CO_2 baited traps. Viral infection and transmission rates were also used to measure viral activity.

Heavy winter snowfall resulted in a winter snowpack more than 400 percent above normal in the high mountain watershed areas of the Kern River. In addition, February, 1969, was the second wettest February on record. The resulting runoff prevented the usual draw-down of Lake Isabella, the flood control reservoir on the Kern River. The spring snow melt was followed by the highest level of water flow in the Kern River on record. In addition to the water diverted to the usual subsurface ground water percolation beds, extensive flooding occurred along the lower reaches of the Kern River below Bakersfield. Water was diverted from the Kern River to Tupman Slough, where it flowed north into the Goose Lake Drain and on into Tulare Lake. Later, the flow into Tulare Lake was blocked and the flow was confined to an approximate 20 square mile area west of the Kern Wildlife Refuge along the Kern-Kings County line. For a period of time, water from the Kern River was even pumped into the newly constructed California aqueduct.

River flows (Table 1) and climatic data (Table 2) and other data are compared with 1958, another year of high water flow and 1968, a year when water flow was substantially below normal. In contrast to 1969, both of these years had moderate to substantial Western equine encephalitis and St. Louis encephalitis activity.

Vector Populations and Arbovirus Activity

While extensive areas of breeding were reported by Kern MAD personnel early in the spring, large numbers of *C. tarsalis* were not observed until late spring (Table 3). In contrast, in 1958, and to a much lesser extent in 1968, an early spring peak occurred in late April. Peak populations of *C. tarsalis* occurred in early July in 1969.

Table 1. Total annual outflow from Isabella Reservoir into the Kern River for selected years, 1958, 1968 and 1969.[1]

YEAR	ANNUAL FLOW (Thousand Acre Feet)
1958	1,176.8
1968	482.8
1969	2,029.3

[1] Courtesy of Kern County Land Company, Bakersfield, California.

Table 2. Climatic conditions in Kern County for three selected years, 1958, 1968 and 1969.[1]

Month	Avg. Temperature			No. of Days above 100°F.			Avg. of days departure from normal			Precipitation Total H_2O Equivalent (inches)			Avg. Departure from Normal (Inches)		
	1958	1968	1969	1958	1968	1969	1958	1968	1969	1958	1968	1969	1958	1968	1969
January	48.3	47.9	48.9	0	0	0	1.4	0.5	1.5	.93	0.49	2.12	–.09	–0.68	.95
Feburary	56.9	58.9	51.1	0	0	0	4.4	6.9	– .9	1.55	0.56	2.83	.43	–0.58	1.69
March	53.9	59.8	56.7	0	0	0	–3.2	2.9	– .2	2.05	1.01	.29	.94	–0.05	–.77
April	61.4	65.4	63.5	0	0	0	–1.6	2.4	.5	1.48	0.66	1.10	–.87	–0.15	.29
May	72.0	70.2	74.3	0	0	2	1.8	–0.2	3.9	.88	0.06	.08	.53	–0.16	–.14
June	75.4	81.2	76.7	1	12	0	–1.5	4.1	– .4	T	0.0	T	–.09	–0.09	–.09
July	82.4	86.6	86.3	9	18	16	–1.8	2.3	2.0	.0	T	T	–.01	–0.01	–.01
August	85.7	79.8	86.2	11	9	21	3.9	–1.9	4.5	.01	T	T	.0	0.0	T
September	76.9	76.9	80.8	2	3	7	1.3	0.4	4.3	.56	0.0	T	.49	–0.08	–.08
October	71.5	66.2	64.6	0	0	0	5.0	–0.6	–2.2	T	1.29	T	–.37	0.97	–.32
November	56.1	55.7	58.3	0	0	0	–0.1	–0.2	2.4	.38	0.40	.42	–.05	–0.09	–.07
December	52.4	47.0	51.1	0	0	0	9.7	–1.8	2.3	.02	0.67	.16	–1.01	–0.3	–0.81

[1] U.S. Weather Bureau, Meadows Field, Bakersfield.

Table 3. *Culex tarsalis* population indices from New Jersey light traps operated in different enviroments in Kern County for selected years 1958, 1968 and 1969.

	URBAN			RURAL			SUBURBAN-RURAL PERIPHERY		
DATE	1958	1968	1969	1958	1968	1969	1958	1968	1969
4-1	--	0	0	76	1	2	0	1	< 1
4-8	--	0	0	67	12	1	< 1	1	0
4-15	--	0	0	131	15	1	< 1	< 1	< 1
4-22	--	0	0	161	5	2	1	1	0
4-29	--	0	0	249	2	8	2	2	1
5-6	< 1	0	0	48	4	4	2	1	1
5-13	3	0	0	88	1	5	2	< 1	2
5-20	16	0	0	324	3	17	8	1	5
5-28	3	0	0	28	6	18	15	3	3
6-4	5	0	0	104	2	15	20	1	4
6-11	24	0	< 1	208	5	14	18	1	2
6-18	10	0	< 1	43	7	34	33	2	3
6-25	37	0	< 1	67	9	51	39	2	5
7-2	8	0	< 1	434	4	72	17	2	7
7-9	4	0	0	658	9	105	21	3	6
7-16	4	0	< 1	62	8	62	15	6	9
7-23	3	0	< 1	144	13	52	13	9	11
7-30	3	0	< 1	86	24	26	34	9	5
8-6	1	0	0	204	24	25	21	2	5
8-13	3	0	0	207	3	23	9	1	4
8-20	2	0	0	62	1	12	12	< 1	2
8-27	1	0	0	124	3	6	13	< 1	4
9-3	6	0	0	73	2	6	30	1	3
9-10	1	0	0	65	7	9	5	0	2
9-17	1	0	0	36	3	7	3	1	1
9-24	4	0	0	23	2	17	6	1	1
10-1	2	0	0	52	1	14	4	1	1
10-8	--	0	0	--	4	9	--	1	1
10-15	--	0	0	--	< 1	6	--	< 1	1
10-22	--	0	0	--	< 1	4	--	< 1	1
10-29	--	0	0	--	< 1	2	--	< 1	< 1
Average	4	0	< 1	151	5	21	13	2	3

Table 4. Viral infection rates in shelter-collected *C. tarsalis* and immunologic conversion rates in sentinel chickens for selected years, 1958, 1968 and 1969, Kern County.

YEAR	INFECTION RATE/1,000			IMMUNOLOGIC CONVERSION RATE		
	WEE	SLE	TURLOCK	WEE	SLE	TURLOCK
1958	8.0	0.9	–	45	32	–
1968	6.4	0.3	0.4	14	1	3
1969	0	0	2.1	0	0	5

Table 5. Proportion of gravid to engorged *C. tarsalis* collected in shelters in two locations in Kern County, 1969, compared with collections in 1958 and 1968.

YEAR	LOCATION	NO.	GRAVID[1] PERCENT	ENGORGED NO.	ENGORGED PERCENT
1969	JERRY SLOUGH	367	13.9	1916	86.1
	MAIN DRAIN BRIDGE	905	86.9	136	13.1
1968[2]		133	11.1	1066	88.9
1958[2]		1776	61.6	1110	38.4

1 Engorged: any non-deplete specimen with visible trace of blood in abdomen.
Gravid: any specimen containing eggs but without trace of residual blood.

2 Collections from all areas during June and July.

Table 6. Number and percent of female *Culex tarsalis* which contain eggs when collected as pupae and held for 10 days on 5 percent sugar water after emergence.

SOURCE	DATE EMERGED	DATE EXAMINED	NO. WITH EGGS	NO. WITHOUT EGGS	TOTAL EXAMINED	PERCENT GRAVID
Kern River	7/11,15	7/25	47	45	92	51.1
Buena Vista	7/15	7/25	26	2	28	92.8
Commanche Pt.	7/15	7/25	5	0	5	100
Rio Bravo	7/12, 15	7/25	17	12	29	58.6
Kern Refuge	7/11, 15	7/25	8	2	10	80.0
J. Dale Ranch	7/16	7/25	1	0	1	100
James Ranch	7/15	7/25	3	1	4	75.0
TOTAL			107	62	169	63.3

Table 7. Cases of encephalitis reported from Kern County, 1968 and 1969, and final etiologic diagnoses.

Etiologic Agent	Number of cases	
	1968	1969
Western encephalitis	2	0
St. Louis encephalitis	1	0
Echo	3	4
Mumps	7	3
Herpes	4	2
Measles	1	0
Bacterial	1	0
Coccidioidomycosis	1	0
Undetermined	27	6
Total	47	15

Despite the fact that expected high populations of *C. tarsalis* did occur, there was no evidence of western encephalitis or St. Louis encephalitis virus activity. In contrast, there were numerous isolations of Turlock virus from pools of *C. tarsalis* collected in shelters, chick-baited traps and CO_2 traps. Similarly, none of the sentinel chickens showed evidence of infection by immunologic conversion to WEE or SLE viruses, while 5 percent had haemoglutination inhibition antibodies to Turlock virus (Table 4).

Evidence of Autogeny

For many years, *C. tarsalis* collected in shelters have been classified into three groups when tested for virus:: engorged (fed mosquitoes including all with any trace of residual blood); gravid (mosquitoes containing eggs but no trace of residual blood); deplete (without detectable eggs or blood). Normally, of these mosquitoes in shelter collections that were not deplete, the great majority were classified as engorged, with only a small proportion classified as gravid. The ratio of deplete to non-deplete (engorged and gravid) varied with the time of year.

Early in the summer of 1969, it was observed that while in the Jerry Slough area, the usual high proportion of engorged to gravid specimens were taken in shelters, at another collection site (Main Drain Bridge) near the extensive flooded areas in northern Kern County, reverse proportions were observed. Examination of shelter collection data for 1958 and 1968 revealed that while the usual high proportion of engorged to gravid were collected during 1968, the proportion of gravid was greater than engorged in 1958 (Table 5).

Since this increased proportion of gravid specimens could be a result of autogenous development of eggs, pupae were collected by Kern MAD personnel from various breeding areas and reared in the laboratory. Emerged females were held for 10 days with access to 10 percent sugar solution and examined for signs of egg development. Autogeny rates from these reared specimens ranged from 51.1 to 100 percent (Table 6).

Discussion

The complete absence of any evidence of WEE and SLE activity was not limited to Kern County, but rather was a general state-wide phenomenon. However, it is of interest to compare various parameters that have in the past been associated with arboviral activity. The year 1958 was characterized by flood conditions comparable to 1969. *C. tarsalis* populations were extremely high and both WEE and SLE viruses were very active, resulting in a number of human cases to both viruses. The year 1968 was also a year when both WEE and SLE viruses were moderately active, with confirmed human cases for both viruses, but was a year characterized by below normal rainfall and river flow and with relatively low mosquito populations. In 1969, breeding areas created by flooding were extensive, mosquito populations were high, although substantially less than 1958, but there was no detectable WEE or SLE virus activity.

Temperature conditions were similar for all three years, although 1958 had fewer days over 100°F. During 1958, and to a lesser extent in 1968, an early spring peak occurred in the *C. tarsalis* population in April, with a second major peak occurring in midsummer. This early spring peak was not detectable in the 1969 *C. tarsalis* population indices.

Autogeny appears to have occurred during both 1958 and 1969. It is not known whether this was a reflection of larval diet in newly flooded areas or a reduction of host availability due to elimination of avian habitat by flood waters. Nor is it known what influence this had on the absence of WEE and SLE virus activity.

Despite the high river flow, areas of flooding were much less in 1969 than in 1958, due to better transportation and disposal of excess water. In addition, a substantial reduction in agricultural sources of *C. tarsalis* production has occurred in the ensuing decade from 1958 to 1969. As a result, during 1969, high mosquito populations were limited for the most part to the flooded areas. Urban and rural community periphery *C. tarsalis* indices were similar to previous non-flood years (Table 3). Even had WEE or SLE viruses been active, the risk of disease in human populations in Kern County would have been substantially less than in 1958.

TARGET ORGANISMS

Melvin L. Oldham, Chairman
1969 Committee of the Future
California Mosquito Control Association

1969 should serve as a warning that beginning now we must take a new approach, remember what we have learned and be ready to re-orient and update our efforts toward our target organisms.

Some of last year's events to think about are: (1) the epidemic that didn't develop, (2) *Aedes* and *Culex* resistance, and (3) the public and political attitude toward the environment. These are not listed in any order of importance except that they occurred almost suddenly in our immediate past, are currently obvious and most assuredly will have a definite and serious impact upon our future.

If the epidemic had occurred we would have sprayed away, reveling in the belief that our spraying prevented a more serious epidemic. But what would we have learned? However, nothing happened. Why? If we say it was because of the spraying that was done, we are playing ostrich and I think we should be smarter than that. We have been left with many questions and dangling theories as a result of the "non-epidemic" and part of our future lies in answering the questions and realigning the theories.

Lessons learned in this respect also may be applied to other vector-disease relationships, such as the malaria possibility in the Sacramento Valley. *Anopheles* are here in great numbers; there are returning veterans from malarial areas and malaria cases have been increasing in the state. What are the possibilities? Do we have to worry about the disease as well as the annoyance factor?

Insecticide resistance is the direct result of our taking the easy way out and our sins have caught up with us. We have watched *Aedes* resistance developing over a number of years but with a certain degree of indifference because there was always a new "easy out" available. The suddenness of *Culex tarsalis* resistance was a shock, not because we didn't know that it would eventually occur but because we thought we had several years and several more "easy outs" to go.

The public and political attitude toward the environment has been simmering for quite a while, especially since "Silent Spring" days. Last year it reached the boiling point. In the 1970's it will undoubtedly boil over. As mosquito abatement districts we have had relatively little effect one way or the other in creating this attitude; nevertheless, we have been and will be affected by the results of it. What will we do?

We are entering a new decade. It seems obvious that we must also start in a new direction in mosquito control. The resistance situation alone will require us to initiate a significant change in our control program in a direction away from such complete dependence upon insecticides. Public concern with environmental contamination and more restrictive insecticide legislation are factors which will also guide us along our new direction.

Which direction will we go?

With our present technology there are limited choices. The most positive, of course, is source reduction, but this is often expensive and can become complicated, especially if we attempt to use the legal means provided in the law, so most of us advocate, support but put off any serious source reduction until "next year". In spite of our reticence if we are to continue controlling mosquitoes, source reduction will most likely be the necessary route until research provides satisfactory biological or naturalistic techniques, some highly specific safe mosquitocides, or other satisfactory alternatives.

Between now and the time our new "direction" becomes effective there will be more mosquitoes. In mosquito abatement districts where mosquitoes do occur there will be fewer catches of 0.1, 0.3 or even 5.0 mosquitoes per trap night.

More mosquitoes will bring us into contact with our most pestiferous organism of all –– people, which in turn brings up the topic of public information. During the next decade we will have to increase vastly our public relations and educational activities on radio, television, in newspapers, for schools and other organizations. This information must be accurate, timely and understandable.

Many of you no doubt receive announcements from your local U.C. Extension Service of various countywide agricultural meetings on fruits and nuts, livestock, pastures and other agricultural topics. Seldom if ever do these meetings include anything on mosquitoes. I think we are missing a bet by not working with Ag Extension to include mosquitoes or to have public meetings on mosquitoes exclusively. We certainly have the personnel, talent and knowledge to participate and would not only provide public information and education but might stimulate some agriculturalists to practice source reduction. The public and political attitude toward the environment has a direct relationship to us and our activities, and we can best stay on the good side of the public by having an excellent public education and information process going.

If there are any University Extension people here today I invite them to work with us to set up a procedure to include mosquito control in their agricultural meetings throughout the state.

To talk on mosquito abatement district target organisms and cover mosquitoes only, would be gross neglect so at this point I will touch on other animals that we know will be more in our future. Most of the things required for mosquitoes will also be required for these pests: source reduction where possible, biological and naturalistic control, highly specific strategically placed pesticides and timely public information.

Few of us have escaped involvement with aquatic gnats and midges and many are actively involved in their control. They are reported as pests throughout the state in recreational and residential areas, painting activities, food processing, manufacturing plants and a variety of other situations. Being products of water impoundment and development, the expanding California water projects and the ever increasing human population will continue to merge people, gnats and midges, creating more need for our services.

The burgeoning population figures remind us that a necessary side product is waste, both liquid and solid, with quantities in the millions of gallons and tons. Public concern will preclude disposing of this in the customary manner. New disposal methods are being developed as rapidly as technology permits but there will be a time lag during the conversion period. The interim will mean additional target organisms for mosquito abatement districts, more aquatic gnat production from sewage and waste treatment plants and oxidation ponds, and flies and rodents from the solid waste products. Although technology eventually may develop waste disposal processes so efficient, effective and complete that pests will not be produced, today rats are involved in every phase of our food supply. Even if the waste problem is solved they will still need to be controlled and we may be assigned the task.

The list of organisms can go on and on, including yellowjackets, wasps, wild bees, ticks, conenose bugs and fleas, to name but a few. Without a doubt this decade and the ensuing years will expand our field of target organisms and include a greater variety than we now cover. However, we must be careful to stay within our bounds and not encroach into the field of private enterprise. We should keep to organisms that affect the public health and comfort which are beyond the control of the individual or private enterprise. We might consider this as a possible definition of our target organisms: "Arthropod and vertebrate organisms affecting public health and comfort where the scope of control is not within the range of the private individual."

Research will play an important and necessary part in providing the ways and means for our future involvement. Indeed, without research on an expanding scale we are liable to founder in chaos and hopelessness. It will be necessary for us to work more closely with research agencies both public and private to ensure that effort is directed toward our goals and we must be prepared to support physically and financially these programs and projects.

In addition, we must consider seriously more arrangements with private enterprise and other public agencies where our control programs will mesh in a complementary capacity.

The decade of the 70's is upon us and is the beginning of a change in all facets of human endeavor. Being a part of this endeavor, we must be prepared to take a new direction in relation to our past target organisms and to accept new target organisms as our responsibility in the future. Because we are and will be working for the public, with the public and under public scrutiny we must be accurate, right and straight-forward in all activities we undertake. Our expertise must be tuned to the peak of perfection.

PRESIDENTIAL MESSAGE

Kenneth G. Whitesell, President
California Mosquito Control Association

In looking back over the many Presidential Messages, I saw a constant duplication in reference to "our problems". Have we not solved any problems? Certainly we have solved many, but we still have two of the same old problems. In the beginning of the 60's we saw resistance to our insecticides as well as rumbles on environmental contamination. Now these two subjects are real and here. We in mosquito control have and will continue to have a devotion and dedication to our job and its surroundings. We have been, and will continue to be, proper and precise in our applications of any pesticides. We have, over many years of insecticide dispersal, been highly conscious of our duty and devotion to preservation of the ecology around us. We are trained, dedicated, devoted, and experienced mosquito control people. We have been and will continue to be strongly aware of the ecological world around us, its protection and preservation. Let the anti-pesticide campaigner come around and we will educate him to our side of the coin. I am willing to venture a statement that there has not been a single one of us who has been involved in a research project, that did not invite and have around us in the project, people from many agencies who would monitor and evaluate the environment within and around this project.

In working with this cooperative idea, we have solved the number one problem in this world, and this is communication between man. As long as we maintain these lines of communication, we will survive, progress, and function in an orderly manner. This line of communication I sincerely and deeply hope you will maintain with me as your President of this the California Mosquito Control Association.

I would like to extend thanks from the Association and myself to our now President-Elect Fred DeBenedetti and his technical consultant Les Brumbaugh for this very fine program; to Mel Oldham and George Umberger and others from the Sacramento Valley Region for their good job on local arrangements, and to all the commercial exhibitors for their participation. Last, but certainly not least, a humble thanks to the speakers and audience for their attendance. The Association invites you to the 39th Annual Conference in Oakland in '71.

I declare this 38th Annual Conference of the California Mosquito Control Association officially closed.