GILBERT L. CHALLET

PROCEEDINGS AND PAPERS

OF THE

Thirty-third Annual Conference of the

California Mosquito Control Association, Inc.

AT THE

MISSION INN

RIVERSIDE, CALIFORNIA

JANUARY 24-27, 1965

Proceedings Committee

W. DONALD MURRAY, *Chairman*

THOMAS D. MULHERN, *Editor*

CALIFORNIA MOSQUITO CONTROL ASSOCIATION, INC.
1737 WEST HOUSTON AVENUE
VISALIA, CALIFORNIA

PUBLISHED DECEMBER 30, 1965

FONTES ABBEY PRESS OAKLAND, CALIFORNIA

1964 OFFICERS AND DIRECTORS OF THE CALIFORNIA MOSQUITO CONTROL ASSOCIATION

1964-65 CORPORATE MEMBERS OF THE CALIFORNIA MOSQUITO CONTROL ASSOCIATION

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

1965 EXHIBITORS, SPONSORS, AND SUSTAINING MEMBERS
CALIFORNIA MOSQUITO CONTROL ASSOCIATION

ALASKA TRANSPORTATION CO.
San Jose Municipal Airport
San Jose, California

ALCO CHEMICAL CO.
19220 Pioneer Blvd.
Artesia, California

AMERICAN CYANAMID CO.
Agricultural Division
P.O. Box 400
Princeton, New Jersey

CHEMAGRO CORPORATION
Kansas City 20, Missouri AND
5090 N. Roosevelt, Suite 5
Fresno, California

DURHAM CHEMICAL CO.
4124 E. Pacific Way
Los Angeles 23, California

INTERNATIONAL HARVESTER CO.
P.O. Box 4024
Oakland 23, California

KAISER JEEP SALES CORPORATION
Western Region
185 Valley Drive
Brisbane, California

MEDINA AIRCRAFT CO.
3425 Lakewood Blvd.
Long Beach 8, California

MOYER CHEMICAL CO.
P.O. Box 945
San Jose, California

NIAGARA CHEMICAL CO.
FMC Corporation
P.O. Box 1669
Fresno, California 93717

SIERRA AIRCRAFT
401 Newhall Street
San Jose, California

SNOW AERONAUTICAL CORP.
P.O. Box 516
Olney, Texas

SOLO INDUSTRIES
37-41 57th Street
Woodside 77, New York AND
1844 Woodhaven Way
Oakland 11, California

F. M. SPEAKMAN CO.
241 Quint Street
San Francisco 24, California

STAUFFER CHEMICAL CO.
500 South Virgil Ave.
Los Angeles 5, California

WILBUR-ELLIS CO. (RED-TOP)
P. O. Box 1286
Fresno 15, California

TABLE OF CONTENTS

CALIFORNIA MOSQUITO CONTROL ASSOCIATION

FIRST SESSION

MONDAY, JANUARY 25, 1965, 9:30 A.M.

J. D. WILLIS, *President*

Ladies and gentlemen of the California Mosquito Control Association:

It gives me great pleasure to open this Thirty-third Annual Conference here at the Mission Inn in Riverside. Fourteen years ago the Nineteenth Annual Conference was held at this same location. It is gratifying that there are with us today many who attended that 1951 Conference.

While we are here, I hope that each of you can spend more time at the University of California. There have been tremendous changes at this campus during the past few years, and I am sure that you will find this to be a highly important campus of the University system.

On behalf of the Association, I offer our sincere appreciation to the many out-of-state visitors who have travelled so far to attend and to participate in the program.

It gives me great pleasure now to introduce Robert L. Metcalf, Ph.D., one of the world's outstanding authorities on modern insecticides.

WELCOME TO RIVERSIDE

ROBERT L. METCALF

Vice Chancellor, University of California, Riverside

It is a pleasure to welcome you to Riverside and to the University of California. It seems impossible that fourteen years have gone by since some of us were here in the Mission Inn for a similar purpose, and I suppose that a few of you might join me in wishing we could roll back the clock and do the last fourteen years over again. Though that isn't possible, I think we can take pride in the many things that have happened since then to help make both the University and the California Mosquito Control Association two better organizations.

The University of California at Riverside didn't exist as such fourteen years ago when we met here. At that time we had here a branch of the Agricultural Experiment Station called the Citrus Experiment Station which had attained considerable fame around the world as a center of subtropical horticulture, with emphasis on research in the culture of citrus.

This branch of the University was started in 1907 and its first headquarters were at the foot of Mt. Rubidoux, at the opposite side of Riverside from the present location. In 1917 the Board of Regents farsightedly purchased 260 acres at the foot of the Box Springs Mountains, a rich agricultural area, and also in that year the first building was erected on the new tract.

There have been subsequent land purchases which have increased the total area to a little more than 1100 acres. In recent years the Board of Regents purchased an additional 830 acres of agricultural land near March Air Force Base, about 10 miles from the present campus. This is a supplementary area for agricultural operations, to which many of the larger projects will be transferred as the present campus land is needed for building space.

In 1954 the Board of Regents, sensing that the population growth throughout California would dramatically increase the demands for higher education, declared Riverside to be a teaching campus and established a College of Letters and Sciences to complement the Agricultural Experiment Station. This was originally thought of as a small and highly elite teaching branch of the University, but people continued to come to Riverside and they wanted to go to school here. Therefore the Board of Regents in 1959 declared this to be a general campus.

This decision was a part of the master plan for higher education in the State of California, in which emphasis in the University is placed on upper division and graduate instruction. It was therefore implied that graduate work would be done here. In 1960 the first graduate program was begun. This has flourished and U.C.R. is one of the most rapidly growing graduate schools in the United States with an increase last year of about 26%. There are now enrolled about 3100 students, of which more than 760 are graduate students. Also, the College of Letters and Science has been joined by the College of Agriculture, which was transferred to Riverside from UCLA in 1960.

There are also some supplementary institutes and centers. The Air Pollution Research Center has a statewide responsibility. The Dry Land Research Institute has been established, which envisions a complete approach to the problems of arid lands, from their cultural, their agricultural, their economic and other aspects, and which should assume much world-wide prominence in the future. This has been financed by a grant from the Rockefeller Foundation of $260,000.00 for the first year's efforts. Plans are being made for an additional very substantial grant proposal to the Rockefeller and Ford Foundations, which would provide for research to complement the present work on the development of domestic arid lands, by including substantial overseas operations in many of the arid regions of the earth, to take to these regions the solutions as we see them here, and to send people there to learn of the problems first hand.

The Riverside campus is grownig phenomenally, and this accounts for the construction and the disturbance and the tearing up of roads. The first buildings that are planned specifically for graduate instruction are now being completed. These include Physical Science Unit 3, a large Physics building; and Physical Science Unit 4, a Chemistry building. Under construction is an agricultural chemicals and environmental pollution laboratory financed in part by a grant from the United States Public Health Service. This laboratory will be devoted to a study of the problems of contamination of air, land and water, with principal emphasis on analytical techniques for detecting small amounts of pollution.

A new Student Union building, financed almost entirely by non-state funds, will be started shortly. Construction will soon start on an Agricultural Science building, which was long deferred and is now provided for by the passage of Proposition 2, which will also provide for a new Life Science building and a Classroom and Office building.

The Riverside Campus has long had a vigorous program of entomological research, devoted in the early days mostly to citrus and subtropical fruits. Since 1946 there has been interest in problems relating to the biology and control of mosquitoes and other pests such as flies and gnats. I must confess that this increase of interest coincided with my arrival here in Riverside in 1946, and since that time there has been a considerable amount of expansion of research in this area. We now have in the Departments of Entomology and Biological Control a total of eight academic staff members and about sixteen technicians specializing in such insect control problems; a considerable research effort indeed. This is in addition to the teaching program in Entomology which was started in 1960. There are now forty-three graduate and seven undergraduate students. Undergraduate instruction is offered in all phases of entomology: systematic, ecological, agricultural, medical, various aspects of the chemistry and toxicology of insecticides, insect physiology, morphology, and biochemistry, and biological control. It's really a very vigorous and flourishing program! There are many foreign students, complemented by carefully selected students from this country.

Several other activities enhance this program. We have a U. S. Public Health Service training grant on the chemistry and toxicology of insecticides, which provides graduate fellowships for nine students each year, in addition to two post-doctorate students. There is a vast shortage of entomologists of all descriptions, but with new federal and international programs, the shortage of insect toxicologists seems to be very critical, so this program is a very timely and vigorous one.

The World Health Organization sponsors another program, in collaboration with a number of other laboratories throughout the world, which is devoted to the selection and development of new insecticides for vector control programs throughout the world.

It has been a pleasure to be with you here this morning and I wish you every success in your forthcoming meeting.

President Willis: We are fortunate to have with us to present the keynote address, George A. Baker, Vice-President of the Los Angeles headquarters of the Bank of America. He is a veteran of thirty-five years of banking, and was named to his present post in 1960.

He has been a city councilman in Huntington Park and is a past president of the Rotary Club, member of the Domestic Trade and Executive Committee of the Los Angeles Chamber of Commerce, and a member of the National Conference of Christians and Jews. Mr. George A. Baker.

LEARNING TO LIVE TOGETHER

GEORGE A. BAKER

Thank you, President Willis. I know that the majority of you are wondering what a banker is doing on this podium on such an occasion; wondering what on earth he knows about mosquito control. I'm frank to say that the only thing I know about it is that I've been stung by the subject many times!

According to your program, many Ph.D.'s are going to address you, and there are many other experts in this field on the program. It is rather coincidental that Pat Bishop, a newscaster in the Los Angeles area, started his news broadcast this morning with a little statement, a short line of remembrance: "The happy ones are those who know and admit their limitations." You are looking at such a happy one!

The theme of your conference is "Program Balance." The things I shall talk to you about are basic in program balance; I call it "learning to live together." This matter of liking people and of having people like us is fundamental in everything we do. You have a great deal of educational work among the groups with which you associate. You have to do a lot of research work, a lot of committee work, to petition for appropriations for this, that and the other. Any of us must do these things when we are in business or professional life. Our ability to have the people in the groups with which we work appreciate us or like us, and for us to have the same feeling for them, has a tremendous import in being successful.

People differ—even those who may dress alike or who may have a lot of characteristics that are similar. We court each other before marriage; we think we know each other very well, but we find there are many unknowns that show up in the first few years of marriage, and they keep showing up. In time, you begin to realize these differences, some of which you like and some of which you don't like. It is the way we cope with these differences that leads us to getting along with people.

I'm not going to bore you with a lot of personal affairs but I do want to give you several little family illustrations because they are true and close to home. I have a sizeable family of five children. They're practically grown now; four are through college, and one is approaching graduation at USC. Bringing them up has been quite an adventure in life for us, and one that has worked hardships on the pocketbook, as you can well imagine. When five youngsters go through college, no matter how much they work on the side, no matter how much scholarship help they may get, it's still an expensive procedure. So being a banker and not having too much outside income, I had to borrow quite extensively from time to time to help pay the costs. (I always like my audiences to know that over the years I've been well taken care of by the Security First National Bank at a very good interest rate, and it's still taking care of me.)

When all seven of us are home, it takes a heap of livin' in a house to call it a home, as Edgar A. Guest said. And he was right!

My oldest daughter graduated from Occidental College. She was a very affectionate girl and I well remember when she left for school her mother would always kiss her good-by. I usually left the house earlier, but when I was there I exhibited the same parental affection. When she'd check in from a late date, I was usually asleep, like most fathers, but there's something about the lady of the house: when her daughter would sneak up the stairs not wanting us to know what wee small hour of the morning it was, her mama would sit up in bed and call out. She would come in and sit on the edge of the bed, and while I snored on, she and her mother would talk about the date; good, bad or indifferent.

Now my next daughter, who graduated from Stanford University, abhors what she calls slobbering and she is in her late twenties now, still home and unattached. It is a great source of concern to me because in a few years I'll be retiring and I don't want her around! Her mama's enough for me in our retirement days. I'm having problems! I've tried to convince her she's going to have to relax, she's going to have to be more affectionate, she's going to have to be more romantic if she wants to trap a man! She's in the education business, a good high school teacher, and they get almost as much pay as bankers do nowadays. So she just smiles at me and travels to Europe and to Russia and all over the place and has a good time.

Now, the reason I'm mentioning this is because our children are our most precious possessions. We try to rear them a little better than our folks reared us. I have already been well advised by mine that they know they can do a better job than we did. When you're rearing a family such as ours, you'll find out very soon that you can show your love one way for one child but you can't show your love the same way for the others.

You want a happy family, you want a united family, you want peace and harmony in the home, so what do you do? You find a way to reach each one, and you have a happy family with harmony, even though each one in it is different. That is what we must do in life. I don't care what business or profession you are in, from the time you get up in the morning until you go to bed at night you are dealing with people, and they are all different.

I'm actually not talking about family relations, except as an illustration. The ability to get along, to talk to committees, to sell projects, to educate people, is based largely on communication, and a prime aspect of communication is having people like you; you must appeal to them and they to you.

I'm going to offer you seven simple little basic fundamentals. You may then wonder why they invited me here, because you know every one of them! But I'm not apologizing for repeating them. They have to be reaffirmed frequently because in this busy, bustling decade of the 60's we're living in, with all the atomic goings on, the pressures and the increased tempo of living each day, we often overlook these basics, and in overlooking them we miss a great opportunity.

You know and I'm also well aware that you can go to college all your life, take every course in psychology, sociology, and any other "ology" that has to do with human behavior, and you still won't know all the answers! So I'm not professing to give them to you here in this subject of program balance. But I am going to give you seven fundamentals which if put into operation will go a long way toward helping you to increase your ability to deal with people, and in dealing with people you have life balance, and you have program balance, and without it you are not likely to be successful, however brilliant or proficient you may be.

The seven points are based on one fundamental, that from the time we get up in the morning until the time we go to bed at night, each one of us has what we call an ego. I don't know what an ego looks like, how much it weighs, what color it is, what shape it is: it's inside. It's an opinion of oneself, and everybody has it. Some persons have too great an opinion of themselves; we call them conceited, and we don't particularly like them. I'm sure you don't have any of them in this group, but we have some in the Bank of America Then there are others who are not the gregarious type; they are the shy, the retiring, the backward; they don't care too much about meeting people. We put them under the classification of "inferiority complex," whether that's justifiable or not. Somewhere between the two extremes of conceit and inferiority are the majority of us.

May I give you two or three quick little illustrations? When you go to a store to buy a fountain pen, you look at them all. They show you the Parkers, the Sheaffers, the Watermans. You finally pick up one you like and you say "I'll take this." The clerk says, "Now just a minute, sir, you have to try this out because unlike the ballpoint pens that are all similar, these have different types of points (or nibs as we sometimes call them). They are made to suit different types and styles of handwriting, and if it's not what you want we can change it." You take the pen, you start to make circles, going up and down to get the feel of it. Then, because you like it, you automatically start writing your own name. You don't write your wife's name, you don't write your association president's name, you don't write your minister's name, you don't write anybody else's name; you automatically write your own name.

All of you do tremendous things, civically as well as professionally. From time to time you are written up in the newspapers and magazines, with your name attached, and when you come home and pick up the paper or magazine concerned, you read the article. Maybe there's a picture, and maybe you're in that too. You read the article and as your eyes come down to where your name is mentioned, they linger for just a moment. I know they do, even though you may not want to admit it! You read the article, and before you put it away you pick it up again and hold it in your hand. You've read it, but you go back to your name again and look at it a second time. If it's misspelled, you call the local newspaper and you want to know who the proofreader is; you're very embarrassed about the way they garbled your name. If they left your name out by mistake (of course it's always by mistake), you tell the wife, "The next time Johnny brings the paper around, don't give him the $2.00 for the subscription." Or, if you are a scrapbook fiend, you clip the article and put it in the scrapbook.

Then there is the matter of pictures. A photographer takes a group like this. A little later the proofs are sent to you or to your home. Where do you look first when you get that proof? At the head table? Not unless you're up there. You remember where you sat, and this is where you look, and if it's a good photograph of you, you break out into a nice big smile. You put $2.00 in the envelope and say, "I'll take one." But, if you look horrible, if you've got a fork in your mouth, or your eyes are popping, you say, "I've got more of these things at home than I know what to do with, I'm not interested," and you pass it by.

These descriptions are purposely exaggerated but these thoughts are a part of us; they are instinctive. Now there is nothing wrong with ego, I'm not deprecating it. I believe it is a divine spark put there to make us reach a little higher towards the potential which few of us reach. It's there but it should be nurtured and cultivated.

But why all of this? Here is my philosophy! Everybody has this ego, mama has it, all the kids have it, the mailman has it, the postman has it, Dr. Metcalf has it, your President has it, we've all got it in varying degrees. When you realize that everybody you meet has this ego, all you have to learn in order to get along better with them is to realize they have this ego and to build it.

Egos must be built sincerely. Banana oil, flattery, bull or any other vernacular term you may want to use to describe insincere talk or insincere dickerings and dealings never built ego. Maybe you flatter someone. He may say with his vocal cords, "Thanks for the kind words, Joe," but we have a little "silent voice" in our consciousness which nobody else can hear. This says to me "What on earth is he buttering me up for? Ever since I've been here he's done everything to be rude to me, he doesn't like me, he's shown antagonism toward me—what's he want? What's he after? I don't like him." And so it deflates ego. So it must be done sincerely, and if we can't do it sincerely then don't do it. Now here are the seven little things.

No. 1. Why is it that every lady and man here this morning is wearing a badge? (You'll notice I have mine on the right side. I learned years and years ago that it is easier to read a badge on the right side, because when you are coming toward a person you can see it immediately, and you say "Hello Henry," but if he has his badge on the left side you can't read it and he says "Gee that guy can't remember anything, he never knows me.")

So, you have a badge, and on that badge is what? Primarily your name, and I notice most of you also have the name of the district and the area from which you come. I have "Bank of America" there to identify me.

Learn to call a person by name! This is one of the fundamentals in dealing with people. Your name is part of your ego, and it is a tremendous thing. We like people when they remember our name. You are introduced to somebody and you don't see him again for a few weeks, then he says, "Why Mr. Baker, how are you?" and I say with my vocal cords "very well, thank you," and I think "My gosh, what a memory, he's seen me once and he remembers my name. I like him, I'm coming back here."

You wear badges because you don't see each other too often, and calling a person by name breaks down some of the strangeness of the convention. Service clubs everywhere use badges. Even with small seminars of 18 or 19 persons, badges may help because it's important to use the names.

This is now more important than ever because automation operates data processing of all kinds through numbers. Go into any bank, large or small, and say to the young lady "Good afternoon, my wife and I are having a little difficulty, we haven't been keeping track of our checks. I wonder if you'd please give me my balance?" What does she ask you? "What's your number?" She doesn't care what your name is: "what's your number?" Your account is by number ,and of course you don't remember, so you say "I can't remember the durn number." Then she'll say, sort of disgustedly, "Well, what's your name?" So she'll get your name and cross index for the number, and finally give you the balance.

One of the biggest objections of our customers is that we have depersonalized our relationships with people through automation. So now we're spending hundreds of thousands of dollars to buy projection machines, still and movie, and we're trying to train all employees to call people by name. Remember, ladies and gentlemen, in this program balance, learn to call each person by name!

No. 2. Always exhibit a cheerful attitude. This doesn't mean you have to grin like a Cheshire cat all day long; it means you must be receptive, approachable. If someone comes to you for something you can't give to them, whether it's a product, a service, or advice, send him away saying, "Well, he wasn't able to help much but wasn't he nice; he was so warm, so friendly. I'm going to come back and talk to him again."

A smile is the shortest distance between two hearts. Stand out in the lobby with people milling about in a group where you don't know some of the people. Smile at somebody and ninety-nine times out of a hundred you'll get a smile right back. If it's a lady she might think you're trying to flirt, but generally it works out all right. So always exhibit a cheerful attitude. We are trying to teach our employees this principle. It is very important when you are dealing with people, when you are talking with a committee. A cheerful attitude sells you.

No. 3. Always exhibit good manners. You say, "Manners, that's what the ladies think about, they follow Emily Post. Not us fellows!" But listen: you can build or deflate ego quicker by manners or the lack of manners than in any other way. Things I find as I get into our branches sometimes horrify me. I only hope that some of the other banks are having the same troubles we are, so we don't lose all our business!

For instance, I see girls, and sometimes more mature women, in public positions at statement windows or elsewhere, masticating great gobs of gum, chewing away. I think gum is wonderful, but there's a time and a place for gum and it's not under a desk and it's not in your mouth when you are waiting on people. That is very, very rude. I also see officers, managers, vice presidents, with big cigars or cigarettes in their mouths, and they never take them out when they are talking to people. They wobble them up and down like Groucho Marx. He does it purposely because that's part of his stock in trade, but it's very rude.

Then I see a lovely leather chair placed by the side of each desk, particularly to invite the ladies in, so when they want to talk about some business problems they may be at ease and the proper respect may be shown to them. Yet, how many of our officers ever invite them in? They let the ladies stand outside the rail and they don't even get up off their seats to talk; they just sit there looking up. If I were these women, I would walk out of the bank and go across the street to our competitors, and hope to get better treatment over there. So it's very important: learn to exhibit good manners.

Good manners feed ego; you all know this. Go to some social affair with your wife some evening and there are always one or two mannerly fellows there. Everybody walks in and they stand up and bow and say, "How do you do," and while you are talking to Jim about the baseball game or what the Dodgers are going to do or what your favorite team is, he's ahead of you helping your wife take off her coat; and you know what happens? All the way home that night, all the next day, all the following week, in her own sweet subtle way, she's needling around, "Why can't you be like him?" That's funny, I laugh too! But it's the truth, that's why you laugh; because you know it has happened. So exhibit good manners.

When you are mannerly to people you build their ego. And then they say, "My, aren't they fine, we should get better acquainted with these people, let's bring them into our circle." Or for rude people, "Aren't they ill-mannered? Let's keep away from them."

No. 4. Always listen. Not the kind of listening you're doing to me now, this is your opening session and you want to get started. I mean individual listening. When you are talking to a person, listen to what he is saying and don't watch a shapely blonde as she struts across the horizon. This person knows if you are paying no attention to what he or she is saying. There's nothing more exasperating when talking to an individual than to know as you are saying something that his mind is not on it. It burns me up. You think, "What am I wasting my time here for?"

There is too much of this being done, even at the executive level. Once in a while we have decisions to make—we're supposed to make our own, but sometimes a big decision is called for. You think you know the answer but in a big organization like ours it may affect the over-all policy of the institution. So you want to get the viewpoint of the other executives. And I sometimes say, "Oh nuts! I might as well have done it myself because they don't listen." It's very important. Listen!

When you listen to a person you automatically build his ego. When you speak to your committees you expect them to listen to you. By the same token, listen to those who may criticize or question something you bring up. Don't hop on them and start breaking them off. Let them say what they have to say. They may not agree with your theory or what you want or the amount of money you want. Let them talk, and always listen, it builds their ego. When you don't listen it deflates them.

And to you young fathers: This applies wonderfully in the home. We applied it with our five children through all the years. When you come home some night and your wife tells you that your next door neighbor is all het up about your son, he's broken a pane of glass in the greenhouse, do you go in there and listen to the kid or do you hop all over him? Listen! There are two sides to every question, and maybe he has a different explanation than the neighbor had, so it helps to build good will at home. So remember: listen!

No. 5. Always have a sympathetic attitude.

Let me tell you my prize story as an illustration. And all of these little stories I'm using about my family are true. They are not faked to color my talk, they are part of my life.

When we lived in Huntington Park and had just three children, two of them were going to high school and one to junior high. They came home and said they needed money for student body dues, advance payments for their annuals, fees for various social functions, etc. So this particular evening I said, "Go up and get my wallet which is on my dresser, and take what you need." The next morning Mrs. Baker said, "By the way, George, I forgot to mention to you that there's a big sale down at Robinsons and some of us girls are going down for lunch and to have a little fun. I wonder if you have $25.00 around that I could use." I said she could look in my wallet, so she went up and looked but said the kids had raided it and there wasn't enough left.

I said, "Oh, this is simple, I'll make out a check and give you my card. Go to our branch and you'll have no trouble cashing it." (By the way, I handle all the banking in our home. We have a joint account but because I've been reared as a bookkeeper, naturally my wife lets me do it. She's not used to it.) So the next day she went into the particular branch and walked up to the lady teller, gave her my card, and said "I'm Mrs. Baker, here's my husband's card. I don't know whether you know him or not but I needed a little money this morning and he decided I could come down here and cash this $25.00." Now if she had been an alert teller, she'd have picked up the card and said, "Baker, let's see? No, I haven't met your husband yet, I'll have to meet him." Then my wife said, "This check is payable to me, Gertrude Baker. I know I'm supposed to sign it somewhere (she meant endorse it, of course). I wonder if you'd tell me what I'm supposed to do." If the teller had been smart, she would have said, "Why, Mrs. Baker, just sign your name on the back," and while she was signing she'd have counted out the $25.00. But do you know what she did? She put her hands on her hips —this is what my wife said and I'm sure she told the truth—and she looked at her and said "Do you mean to tell me that you don't even know how to endorse a check?" My wife grabbed the check, walked out of that bank, and to this day, fifteen years later, hasn't put a foot inside a branch of the Bank of America, from which I get my living! I tell her she should never carry a chip that long, and of course she shouldn't. This is an appalling thing. But suppose that instead of being George Baker's wife, she had been the wife of the President of the University of California, or of the Union Oil Company. You know what would have happened inside of twenty-four hours? I'm sure you do. There would have been a few accounts transferred. The point I've been trying to make is: have a sympathetic attitude.

A lot of us don't know the technicalities of your field. All we know is that we have an undesirable pest that brings a lot of trouble and sickness. When you talk to the people about mosquitoes, have a sympathetic attitude and explain the background in language they can understand.

We have taken people on tours of our tremendous automation equipment. We had several guides (I went around a few times) and I said, "Get these fellows off this tour, they are talking data processing language and these people don't know what on earth they are talking about. Get some fellows as guides who can put into lay language all the marvelous things these instruments can do." We've done this and now everybody enjoys it because we explain in simple language. Be sympathetic. If you are sympathetic with people you automatically build their ego.

No. 6. Never high-hat. No matter how superior you may be in your particular field, how wealthy you may be, how many letters you may have attached to your name, no matter how important you may be in a community, never try to let the other people know; they'll find out. I found out today, I read your program. I looked at the names of all the Ph.D.'s you are going to listen to. I know there are a lot of them here, they don't have to tell me. Then as you meet them, they've already built an ego. As you find out that they are so much more important than they ever expressed themselves to you as being, that doubles your ego because you say, "Well, just think, he treats me as if I were a brother or sister or good friend. I never knew he was such an important man. I never knew he was the wealthiest person in town. I never knew he was one of the brainiest men in this field in the United States."

When you go into see Jesse Tapp, the chairman of the board of our bank (and this is the only plug I shall get in for the bank), he, if anybody, has the right to strut around his office with his thumbs under his armpits saying, "Look what a big boy am I," because he's the chairman of the board of the world's largest bank.

A lot of you know him or should know him, because he's very active in agricultural affairs and other things in this state; soon he'll be retiring. But does Jesse strut around? He's the kindest, sweetest, most understanding yet deeply intelligent man you'll meet anywhere, and people are amazed. You can go to him with any kind of a problem and he'll talk to you about it. Good heavens, you'd never think he was the chairman of a bank he's so normal, so human, so understanding. That's humility.

Being humble doesn't mean groveling at a person's feet or letting him walk over you. Humility is acknowledging that you have to have help. This morning the happy ones are those who know and admit their limitations. That's a form of humility, isn't it? Few if any of us get to where we are alone. Sure, we have to be capable and well educated; we have to know our business in order to progress and be promoted. Yet there are literally hundreds who contribute to our reaching that goal. The wonderful secretaries we have; how they cover up for us and how they help us! And a lot of other individuals who are a part of the team all the way down the line. They do efficient work for which we get credit, and sometimes we're not half as good as we appear to be. We must never forget their efforts, we must always remember them, and when we get moved we must give them due credit. When we are humble, no matter how important we may be, we automatically build the other person's ego, and he loves it.

No. 7. Don't argue. What do you do when you argue? You show the other fellow he's wrong. Well, he may be wrong, but argument accomplishes nothing. Then what are you supposed to do? Agree with him just to build his ego? No, you must do this sincerely and if you don't agree with him you wouldn't be sincere if you pretended to. You listen to him, exhibit good manners, you are cheerful, you are sympathetic. When he gets through giving you his viewpoint, no matter what subject it's on, even though you don't agree (he usually knows you don't, he wouldn't be discussing it with you if he knew you were in agreement), you may say, 'Well, Henry, I appreciate your viewpoint. There are a couple of things you mentioned that I'm going to check into further, I need some enlightenment on them, and yet on the other hand, Henry—" and you give him your ideas. Or, "That's an interesting angle, Mary, I'll check on it, and yet there is this other way . . ."

This is what we do in our business. We have more opportunities for argument than any other place. People come in mad over this, that and the other thing. Sometimes I'm worried that they are going to have a heart attack or blow their stacks right there. You sit down with them and say, "We're very sorry you are so disturbed, Mr. Brown. We don't like to have people disturbed. Now tell us, what's your story?" While he's ranting and raving, you let him rant and rave. You don't argue with him even though you are sure he is wrong. He may not be wrong! Then you check up and find out what's the matter. If you or your organization has goofed, as sometimes you have, you come back and apologize to him. "It's no wonder you got all upset, we're sorry about it. This is our error, and if we've hurt you in any way, we'll be glad to correct it and we apologize to you sincerely."

Or, if you find that he goofed, you don't come back and say, "Uh, uh, this one's on you." No sir, you don't. You just say "Well, in going over this matter, we noticed something that could have happened here. We noticed that your wife changed her signature a while ago and now she's not signing it as it appears in our records and this is why the check was returned." Something like this, and then he begins to say, "Oh, yes, I see she didn't do it right, I'm awfully sorry, I'm a bore for being so nasty"—and he walks away. So, don't argue. Don't tolerate argument!

We never tolerated argument in our home. Are we a bunch of angels? No, not from the time there were just two children and only one toy in the playpen; that's the time for an argument, scratching and scraping and pulling. So, you find another toy. If there's not another toy nearby, you get something that's equally soft or not harmful, and you give it to them and say "change off." Then as they grow up you teach them to sit and reason together, as we did. We don't want them to be robots and to think alike, they have their own views and their own different ways, but don't argue! Argument accomplishes nothing. As a result, your family grows up without bickering. There's harmony. There's disagreement of opinion surely, but it's done in a discussion manner in a beautiful way, and you have the peace that a lot of people are looking for.

Now, aren't these principles simple? You knew every one of them. Why did I get up early and fight the traffic, driving all the way out here this morning to tell you this? Because I believe in it. Because I know we forget these things. Remember: everybody has an ego in varying degrees. You learn to get along better with people by building this ego in many, many ways, but remember: Learn to call a person by name, always be cheerful, exhibit good manners, be sympathetic, do not high-hat, be humble, and don't argue.

Gentlemen, let's use the education we have, the proficiency we have in our professions, the experiences we've gathered so far in our life to ever greater effectiveness by including among other things those seven little things I've told you. I know they'll work for you. I appreciate the privilege of being with you. Thank you.

President Willis: Thank you, Mr. Baker. We appreciate your advice. I think that during the next two days it will be put to lots of use, for the good of the Association.

REVIEW OF RECENT RESEARCH ON MOSQUITOES BY THE ENTOMOLOGY RESEARCH DIVISION, U.S.D.A.

W. C. McDuffie, B. M. Glancey, J. B. Gahan, and L. F. Lewis

Entomology Research Division, Agr. Res. Serv., U.S.D.A.

I have not had the privilege of attending an annual meeting of the California Mosquito Control Association and reviewing recent research on mosquitoes by the Entomology Research Division for many years. However, your Association was kept informed of the results of U.S.D.A. research almost yearly by Dr. A. W. Lindquist until his retirement in 1962. My review today therefore will be limited to research during the past 2 years.

Before presenting the results of our research on mosquitoes, I believe I should tell you where this research is being done, and something of its scope at each location. The largest part of our research on mosquitoes is conducted at Gainesville, Florida, by the staff which was moved from Orlando in June, 1963. About half of our research is devoted to screening new compounds for toxicity to mosquito larvae and adults, and to field testing of promising materials as larvicides and adulticides. The other half of our work is devoted to investigations of chemosterilants, attractants, insecticide resistance and biology.

At Corvallis, Oregon, the better larvicides found at Gainesville are tested in the laboratory against *Culex tarsalis,* Coquillett. The outstanding materials are also tested against this and other species under field conditions, especially in log ponds. The workers here are also conducting studies of attractants, especially with regard to oviposition stimuli, and are doing important work on the mode of action of insecticides and the nature of resistance in several species.

Our work at Fresno, in cooperation with the Bureau of Vector Control of the California State Department of Public Health, is concerned with irrigation mosquitoes. The original objective was to study the bionomics and control of these species in relation to land and water management practices. This objective could not be attained, so we have placed major emphasis on the biology of different species, giving some attention to the evaluation of insecticides and chemosterilants and to biological control agents.

Early in 1964 a new station was established at Lake Charles, Louisiana, to study the biology and control of salt marsh mosquitoes. Here, major emphasis is on land and water management procedures to minimize mosquito production, and on biological control agents. This work is under the direction of H. C. Chapman, who was formerly in charge of our work at Fresno.

Research on larvicides—During the past 2 years, approximately 300 new compounds have been screened for toxicity to *Anopheles quadrimaculatus* Say larvae. About a third of these materials were rated as Class IV larvicides (more than 50% mortality at 1.0 ppm). Three of these compounds caused 100% mortality at 0.01 ppm in 24 hours, which is the kill usually obtained with this concentration of DDT against the nonresistant laboratory strain. Eleven compounds were 100% effective at dosages of 0.025 to 0.05 ppm. Data for eight of these compounds are still confidential, but results for the other 6 appear in Table 1.

Table 1. Toxicity of 6 compounds to 4th instar larvae of *Anopheles quadrimaculatus.*

	Percent mortality in 24 hours at indicated concentrations (ppm)			
Company Name and No.	0.05	0.025	0.01	0.005
Amer. Cyan. 52160 (Abate)	100	100	100	74
Bayer 52957	100	100	100	74
Cela G.m.b.H. S-1942	100	100	60	40
Gen. Chem. GC-6593	100	94	56	24
Geigy GS-13005	100	90	22	4
Shell SD-8436	100	60	12	....

American Cyanamid E.I. 52160 was one of the two most effective larvicides. This compound should be of special interest to mosquito control workers because of its very low mammalian toxicity of approximately 3,000 mg/kg. This material has been given the trade name *"Abate"* and will be registered for use in the near future.

Cistern Tests—Although the Entomology Research Division is not involved in the current program to eradicate *Aedes aegypti,* we have been conducting tests at Gainesville to determine the potential of several insecticides as control agents. Since *A. aegypti* breeds prolifically in cisterns in tropical areas, tests were made in cisterns to evaluate the effectiveness of several compounds of relatively low mamalian toxicity. The cisterns were treated with 1.0 ppm of technical insecticides mixed with acetone. At weekly intervals after treatment samples of the water were taken from the top and bottom of the cisterns and tested for toxicity to fourth instar larvae of *A. quadrimaculatus* and *A. aegypti.* The most effective insecticide was chlorthion, which gave 100% kills of both species for 4 weeks. American Cyanamid 52160 and dicapthon were less effective.

During the past 2 years at Corvallis, Oregon, we have conducted extensive tests to compare the effec-

[1]Mention of a proprietary product herein does not necessarily imply endorsement of this product by the U.S.D.A.

tiveness of several insecticides in different formulations for the control of several species of mosquitoes that breed prolifically in log ponds. They have also given attention to control of mountain *Aedes* larvae.

In tests in log ponds we obtained 100% initial control with 0.1 lb/acre of fenthion applied on Durham Duratex H.R® granules or vermiculite. The time interval between treatments ranged from 1 to 2 weeks in different ponds. Applications of 0.1 lb/acre of fenthion with attapulgite granules were less effective, but a dosage of 0.2 lb/acre gave satisfactory control for 12 days. Applications of 0.1 lb/acre of fenthion in SAE30 motor oil, fuel oil, and water were 99-100% effective initially and retarded reinfestation for 7-12 days. In comparative tests American Cyanamid 52160 proved fully as effective as fenthion. Both gave 99% initial control at 0.025 lb/acre, the lowest dosage tested. Dosages of 0.1 and 0.15 lb/acre applied in oil or granular formulations gave 100% kills and were effective about 2 weeks in most test ponds.

In tests against mountain *Aedes* larvae, we obtained 100% control with only 0.05 lb/acre of lindane. Fenthion and American Cyanamid 52160 at 0.1 lb/acre gave 97-100% control of larvae. Several materials, including ronnel, gave very erratic results and failed to give complete control in all tests even when applied at 0.5 lb/acre.

Research on Adulticides—At Gainesville new compounds that have shown high toxicity to human lice and mosquito larvae in screening tests are evaluated for effectiveness against adult *Aedes taeniorhynchus* (Wiedemann). The materials are tested as sprays in a modified wind tunnel by the procedure described by Davis (1959) and Davis and Gahan (1961), with malathion as a standard. During the past 2 years we have evaluated approximately 200 compounds by this procedure and about a fifth of them have rated Class IV (LC_{90} or less than 0.05%). Compounds that were equal or superior to malathion are shown in Table 2.

Table 2. Toxicity of 8 compounds against adult *Aedes taeniorhynchus* in contact spray tests (average of 1 to 4 replicates with 2 cages each; 25 adults per cage).

Company Name and No.	LC_{50} (% conc.) (Estimated)	LC_{90} (% conc.) (Estimated)
Shell SD-8280	0.0019	0.005
Shell SD-8211	.004	.007
Shell SD-8436	.0046	.016
Bayer 42696	.0050	.017
Bayer 47940	.0060	.017
Geigy GS-13005	.0064	.018
Shell SD-8530	.0130	.021
Malathion[1]	.0100	.021
	.020	.045

[1] Results represent means and extremes of LC_{50}'s and LC_{90}'s in seven tests.

The most effective compounds by far were Shell SD-8280 and Shell SD-8211 with LC_{90}'s of 0.005 and 0.007, respectively.

In Florida we conducted a number of field tests in 1963 to compare the effectiveness of Bayer 41831, Bayer 39007, and malathion as aerial sprays for the control of adult salt-marsh mosquitoes, predominantly *Aedes taeniorhynchus*. All materials were applied as emulsions at the rate of 0.1 lb/acre and also tested Bayer 39007 and malathion at 0.05 lb/acre. Bayer 39007 at 0.1 lb/acre showed 99% control at the 3- and 6-hr counts and 96% control after 24 hours. The 0.05 lb/acre application was only slightly less effective. Bayer 41831 and malathion at 0.1 lb/acre showed 96% and 86% control, respectively, after 6 hours, but only 27% and 72% after 24 hours. Malathion at 0.05 lb/acre was relatively ineffective in these tests.

In 1964 our Florida personnel ran aerial spray tests to compare the effectiveness of malathion formulated in an emulsion, a fuel-oil solution, and in a fog-oil solution (specific gravity of 0.92 and molecular weight of 200). All applications were at the rate of 0.05 lb/acre. In these tests the fuel-oil and fog-oil sprays were about equally effective and both were far superior to emulsion sprays. The differences in formulation might not have been so marked at dosages of 0.1 or 0.2 lb/acre. However, in our work over the years aerial sprays of oil solutions of other insecticides have consistently proved to be more effective against adult mosquitoes than emulsions.

During the past year we have heard a great deal about applications of low volumes of concentrated or undiluted insecticides. Enthusiasm for this principle was stimulated by the finding that applications of several ounces per acre of undiluted technical malathion gave more effective control of certain crop pests than larger volumes of dilute solutions and also produced lower residues. The idea here was not new to mosquito control. In 1949 in Alaska studies showed that applications of 0.25 and 0.5 pint of 20% DDT-oil solution were fully as effective as 1.0 and 2.0 pints of 5% DDT-oil solution against mosquito larvae and adults (Blanton *et al.*, 1949; Travis *et al.*, 1949). However, the current concern over residues and harmful effects on beneficial insects, fish, and wildlife dictated that mosquito control workers take another look at the merits of applying concentrated or undiluted insecticides. Results of work along this line in 1964 have not been published. However, I can report that studies in 1964 by T. D. Mulhern and C. M. Gjullin in cooperation with a number of California mosquito abatement districts showed that low volumes of parathion, malathion, and fenthion gave about as good control of mosquito larvae in irrigated pastures and crop lands as the usual volumes of ½ to 1 gal/acre. Much additional work will doubtless be done in 1965.

Similar studies on low volume aerial spraying of malathion were conducted in Florida against adult salt-marsh mosquitoes, predominantly *A. taeniorhynchus*. In these tests, application of 2 oz/acre or more showed over 90% control after 24 hours, but a dosage of only 9.6 oz gave highly effective immediate control (Glancey *et al.*, 1965).

Development of resistance in mosquitoes to DDT and other chlorinated hydrocarbon insecticides has stimulated our research to find new residual insecticides for use in the world-wide campaign to eradicate malaria and other mosquito-borne diseases. During the past 2 years we have evaluated approximately 100 new compounds as residual applications (100 mg/sq ft) on plywood panels against adult *A. quadrimaculatus*. In addition, we conducted field tests in 1963 and 1964 to evaluate the effectiveness of several outstanding materials as residual applications against adults of *A. quadrimaculatus* in farm buildings in Arkansas.

In the laboratory tests over 200 compounds continued to kill 70-100% of the adults exposed on treated plywood panels for 48 weeks. Several materials, including Zectran, Stauffer N-2310, and Monsanto CP-40273, showed about equal effectiveness against resistant and normal strains of adults of *A. quadrimaculatus*. However, the outstanding treatments were those with Bayer 37344 and Hercules 7522-H (plus piperonyl butoxide 1:10); each gave 100% kills of both strains after 96 weeks. Carbaryl in combination with piperonyl butoxide was also 100% effective against the resistant strain for 96 weeks but was slightly less effective against the normal strain.

In 1962 residues of 5 carbamates and 3 organophosphates, including malathion as a standard, were applied at 200 mg/ft^2 in farm buildings in Arkansas (Gahan *et al.*, 1964). These workers did not determine the maximum life of the best materials, since the mosquito season ended before they lost their effectiveness. However, residues of Bayer 39007, Hercules 5727 (or Union Carbide UC-10854), Bayer 41831, Upjohn U-17004, and Hercules 7522-H eliminated all or most of the adult mosquitoes throughout the test period. All these materials were superior to carbaryl, Hooker HRS-1422, and malathion. Further observations in 1963 on buildings treated in 1962 showed that the treatments of Bayer 39007 were almost completely effective after 63 weeks (Gahan *et al.*, 1964). Hercules 5727 was only slightly less effective than Bayer 39007.

In 1963 we applied these same compounds to farm buildings in Arkansas, the better ones at 100 mg/ft^2 and others at the old rate of 200 mg/ft^2. Results showed that Bayer 39007 and Upjohn U-12927 were as effective, at least for 11-12 weeks, at 100 mg/ft^2 as they had been at 200 mg/ft^2 in 1962. Several other materials also gave high control throughout the season. In summary, the 1963 results showed that the malathion standard was inferior to Bayer 39007, Upjohn U-12927, Hercules 5727, and Bayer 41831, about equal to Bayer 37344, and superior to Hooker HRS-1422, and carbaryl.

Cooperative Research with the Department of Defense—One of the most important functions of our Orlando, Florida, laboratory was cooperative research with the Department of Defense on special problems in overseas areas. This relationship is being continued by our new laboratory at Gainesville. In 1963, we conducted extensive tests on Okinawa to evaluate a number of insecticides for the control of both adult and larval mosquitoes (Gahan *et al.*, 1965).

In tests with thermal aerosols (TIFA) against adults of *Culex tritaenorhynchus* Giles and *Culex quinquefasciatus* Say, fenthion and naled gave kills of 90 to 100% with 2 to 6 oz/gal of oil. Bayer 39007 was about equal to these materials against *C. tritaeniorhynchus* but inferior to them against *C. quinquefasciatus*. These three materials were superior to dichlorvos and malathion. DDT was ineffective.

In field tests against larvae of *C. tritaeniorhynchus*, fenthion was the most effective material at the low dosage of 0.05 lb/acre but at 0.1 lb/acre fenthion and naled were equally effective, giving 94% and 95% control, respectively. Trichlorfon and Bayer 39007 were highly effective at 0.25 lb/acre and superior to malathion and DDT.

In 1964 we conducted further studies on Okinawa, but these results will not be included in this review. Similar cooperative studies are contemplated in Southeast Asia this year.

Research on Sterilization Techniques of Mosquito Control — We have continued our research on the chemosterilization of different species of mosquitoes. In general, our research has centered around laboratory studies of the effectiveness of different sterilants, the possible development of resistance to the sterilizing effect of these chemicals, and some limited small-plot field studies on means of utilizing chemosterilants. How to utilize these materials for practical control remains the most serious unsolved problem in developing chemosterilant treatments against mosquitoes. The toxicity of known chemosterilants, along with their unknown but potentially mutagenic properties, may prevent the need for direct treatment of breeding areas. Effective means of utilizing chemosterilants in attractive baits or lures, or in the release of sterile males, have not yet been developed. Consequently, any use of chemosterilants for controlling mosquitoes rests on the ingenuity of researchers and on their elucidation of hazards involved.

You will be especially interested in the results of research with a new compound, hempa (hexamethylphosphoric triamide), which differs structurally from the aziridinyl compounds, and is also much less toxic. Hempa fed to adults of *Aedes aegypti* at concentrations of 1%, 0.5%, and 0.1% in honey-water solutions caused complete or almost complete sterility of adults. Sterile males were at least as competitive as normal, untreated males in mating with virgin, untreated females. However, when adults of *A. aegypti* were exposed to residual deposits of hempa on various surfaces (glass, plastic, masonite, and paper) and larvae were exposed to the material in their rearing water, it caused only partial or no sterility.

Larvae and adults of *A. aegypti* were treated with apholate and tepa to determine whether the males would recover fertility after successive matings. Recovery of fertility was almost complete by the fourth mating with males treated as larvae with apholate. Males treated as larvae with tepa showed less recovery of fertility. There was no indication of recovery of fertility in males treated as adults with residues of tepa (Dame and Ford, 1964).

Studies with *Aedes aegypti* treated with apholate were conducted to determine whether resistance to the sterilizing action of this compound could be developed through selections with substerilizing dosages administered to larvae in treated water. Two colonies of *A. aegypti* developed resistance to the sterilizing action of apholate (Hazard *et al.*, 1964). The importance of resistance in other species or in future control operations remains to be determined; however, results indicated that resistance to chemosterilants might be a problem to be considered in research with these materials.

Our personnel also conducted studies in California to determine the feasibility of using a chemosterilant to suppress a population of *Culex tarsalis* in oases within the Anza-Borrego Desert State Park (Lewallen *et al.*, 1965). Applications of apholate to potholes at the rate of 75 ppm had some effect on the mosquito population, but the study did not provide conclusive results on the potential of the chemosterilization technique under field conditions.

Research on Biological Control—At the present time we must rely heavily on insecticides for mosquito control. However, I am confident that research will in due time produce parasites, predators, and pathogens which will provide as effective control of mosquitoes as our most potent insecticides. The big problem is to find people who are competent in this field and who will sacrifice immediate recognition for long-term chances of success or failure. In this regard, we are depending on W. R. Kellen, Bureau of Vector Control, California State Department of Health, and Harold C. Chapman and E. I. Hazard of our division. These men and their associates have pioneered in demonstrating the possibilities of controlling mosquitoes by means of biological control agents. They have found parasites and pathogens that will kill mosquito larvae. Their problem now is to find ways to establish these organisms in mosquito breeding environments so they will survive and prevent mosquito production. This is a difficult biological problem, but we believe research will in time provide a solution at least for some kinds of pathogens and parasites.

Nature of Insecticide Resistance in Mosquitoes—At our Corvallis laboratory research by Eddy, Plapp, Bigley, and their associates has contributed greatly to our understanding of the nature and mechanisms of resistance in mosquitoes, especially in *Culex tarsalis*. In 1962 they published results on the metabolism of malathion and malaoxon in resistant and nonresistant strains of *C. tarsalis* (Bigley and Plapp, 1962). Malathion was degraded primarily by the formation of carboxylic acid derivatives in both strains. After treatment resistant larvae produced over 11 times more carboxy-esterase derivatives than phosphatase derivatives whereas nonresistant larvae produced only 2 times more carboxyesterase than phosphatase derivatives. Further studies showed that the small amount of malathion converted to malaoxon detoxified much more rapidly in resistant than in nonresistant larvae. These results clearly indicated that resistance to malathion and malaoxon is related to the ability of the resistant strain to degrade these materials more rapidly than the nonresistant strain.

More recent studies reported that certain tris-substituted derivatives of phosphoric acid markedly synergized malathion against resistant larvae of *C. tarsalis* but caused little or no increase in its toxicity to nonresistant larvae (Plapp *et al.*, 1963). The materials used in these tests were rather specific for malathion and did not synergize other organophosphates. These results indicated that with certain synergists resistance to organophosphate insecticides could be overcome by inhibition of degradation mechanisms. Recent studies have shown that certain analogs of malathion and malaoxon overcame resistance in *C. tarsalis*, and gave equally good kills of resistant and nonresistant strains (Plapp *et al.*, 1965).

Another paper, by Plapp and associates, presents results that will further clarify the nature of the mechanism of resistance in mosquitoes. This paper, entitled "Esterase Activity in Mosquitoes and Its Possible Relationship to Organophosphate and Carbamate Resistance," will probably appear in the March 1965 issue of Mosquito News.

The foregoing is only a partial review of a few phases of our program of research on mosquitoes. We are also conducting extensive studies on the biology of several important pest species and on the development of attractants which might be used in control. We are also studying factors affecting oviposition stimuli and are searching for materials that could be applied to water to repel female mosquitoes and prevent oviposition. I will hope to report on this research at another meeting.

Table 2. Chemical Names of Proprietary Materials.

American Cyanamid 52160 (*0,0*-dimethyl phosphorothioate *0,0*-diester with 4,4'-thiodiphenol)
Bayer 37344 [4-(methylthio)-3,5-xylyl methylcarbamate]
Bayer 39007 (*o*-isopropoxyphenyl methylcarbamate)
Bayer 42696 (*0,0*-dimethyl *0*-4-nitro-*m*-tolyl phosphorothioate)
Bayer 41831 (*0,0*-dimethyl *0*-4-nitro-m-tolyl phosphorothioate)
Bayer 42696 [3-(dimethylamino)-*p*-tolyl methylcarbamate]
Bayer 47940 [*0*-(3-chloro-4-cyanophenyl) *0,0*-dimethyl phosphorothioate]
Bayer 52957 [*0*-(5-chloro-1,2-benzisoxazol-3-yl) *0,0*-diethyl phosphorothioate]
Cela G.m.b.h. S-1942 [*0*-(4-bromo-2,5-dichlorophenyl) *0,0*-dimethyl phosphorothioate]
Geigy GS-13005 [*0,0*-dimethyl S-[(2-methoxy-5-oxo-2-thiazolin-4-yl)methyl] phosphorothioate]
General Chemical GC-6593 [1,1-dichloro-2,2-bis(*p*-chlorophenyl)=cyclopropane]
Hercules 5727 (*m*-isopropylphenyl methylcarbamate)
Hercules 7522-H (6-chloro-*m*-cumenyl methylcarbamate)
Hooker HRS-1422 (3,5-diisopropylphenyl methylcarbamate)
Monsanto CP-40273 (*0*-*p*-nitrophenyl *0*-propyl methylphosphonothioate)
Shell SD-8211 [2-chloro-1-(2,5-dichlorophenyl)vinyl dimethyl phosphate]
Shell SD-8280 [2-chloro-1-(2,4-dichlorophenyl)vinyl dimethyl phosphate]
Shell SD-8436 [2-chloro-1-(2,4-dibromophenyl)vinyl dimethyl phosphate]
Shell SD-8530 (3,4,5-trimethylphenyl methylcarbamate)
Stauffer N-2310 [*0*(2-chloro-4-nitrophenyl) *0*-methyl ethylphosphoro=thioate]
Upjohn U-17004 (6-chloro-3,4-xylyl methylcarbamate)
Upjohn U-12927 (6-chloro-3,4-xylyl methylcarbamate)
Zectran (4-dimethylamino-3,5-xylyl methylcarbamate)

References

Bigley, W. S., and F. W. Plapp. 1962. Metabolism of malathion and malaoxon by the mosquito *Culex tarsalis* Coq. Ins. Physiol. 8:545-57.

Blanton, F. S., B. V. Travis, Nelson Smith, and C. N. Husman. 1949. Control of adult mosquitoes in Alaska with aerial sprays. J. Econ. Entomol. 43(3):347-50.

Dame, D. A., and H. R. Ford. 1964. Chemosterilization and its permanency in mosquitoes. Nature 201(4920):733-34.

Davis, A. N. 1959. Laboratory tests with organic compounds against adult salt-marsh mosquitoes. Proc. 46th Ann. Meet. N.J. Mosquito Exterm. Assoc., pp. 186-188.

Davis, A. N., and J. B. Gahan 1961. Wind-tunnel tests with promising insecticides against adult salt-marsh mosquitoes, *Aedes taeniorhynchus* (Wied.). **Mosquito News** 21(4): 300-03.

Gahan, James B., H. G. Wilson, and Carroll N. Smith. 1964. Studies with new insecticides as residual sprays in buildings naturally infested with *Anopheles quadrimaculatus*. Bull. Wld. Hlth. Org. 30:139-45.

Gahan, James B., William W. Young, Neil E. Pennington, and G. C. LaBrecque. 1965. Thermal aerosol and larvicide tests with new insecticides to control two species of *Culex* mosquitoes on Okinawa. **Mosquito News** (in press).

Glancey, B. Michael, C. S. Lofgren, Jack Salmela, and A. Nelson Davis. 1965. Low volume aerial spraying of malathion for control of adult salt-marsh mosquitoes. **Mosquito News** (in press).

Hazard, E. I., C. S. Lofgren, D. B. Woodard, H. R. Ford, and B. M. Glancev. 1964. Resistance to the chemical sterilant, apholate, in *Aedes aegypti*. Science 145(3631):500-01

Lewallen, L. L., H. C. Chapman, and W. H. Wilder. 1965. Chemosterilant application to an isolated population of *Culex tarsalis*. **Mosquito News** (in press).

Plapp, F W., G. A. Chapman, and G. W. Eddy. 1963. Synergism of malathion against resistant house flies and mosquitoes. J. Econ. Entomol. 56(5):643-49.

Plapp, F. W., Richard D. Orchard, and Joseph W. Morgan. Analogs of parathion and malathion as substitute insecticides for the control of resistant house flies and the mosquito, *Culex tarsalis*. J. Econ. Entomol. (in press).

Travis, B. V., K. H. Applewhite, and Nelson Smith 1949. Control of mosquito larvae in Alaska with DDT. J. Econ. Entomol. 43(3):350-53.

THE CURRENT STATUS OF THE *AEDES AEGYPTI* ERADICATION PROGRAM IN THE UNITED STATES AND 1964 SUMMARY OF MOSQUITO-BORNE ENCEPHALITIDES IN THE UNITED STATES

Russell E. Fontaine

U. S. Department of Health, Education and Welfare, Aedes aegypti Eradication Branch, C.D.C., P.H.S.

The current program of eradication of the yellow fever mosquito, *Aedes aegypti,* from the United States and its offshore territories was initiated by the Public Health Service in October, 1963. The program represents an essential and major part of an unprecedented international effort in the field of vector control in which the nations of the Americas have agreed to eliminate the yellow fever mosquito from the Western Hemisphere through cooperative, coordinated action. Eradication of the mosquito was deemed by the nations as the only permanent solution to the problem of preventing urban yellow fever in the hemisphere.

The international program originated in 1947. This action followed agreement by the member countries of the Pan-American Health Organization to a resolution presented by Brazil to eradicate *Aedes aegypti* from the Western Hemisphere. As a member of the Directing Council of the PAHO and one infested with *Aedes aegypti* and therefore vulnerable to the threat of urban yellow fever, the United States Government signed the 1947 pact of eradication together with 26 other member nations. Each nation agreed to conduct a program until eradication of the vector was achieved in the hemisphere.

From the date of the 1947 pact until 1961, only the U. S. among the member nations had postponed initiating an eradication program. However, in 1961, the United States again joined with the nations of the Americas in approving a resolution calling for completion of evaluation in a 5-year period. In accordance with the 1947 and 1961 agreements, Congress in FY 1963 appropriated funds in the amount of $3,000,000 to begin the U. S. program under the direction of the Public Health Service.

The event which spurred the countries to agree to this coordinated, hemisphere-wide vector eradication program was the discovery in the early 1930's that the virus of yellow fever was not endemic in cities. Rather, it was being maintained in the vast jungle areas of Central and South America by a chain of transmission involving primarily monkeys as the vertebrate host and forest dwelling mosquitoes, principally *Haemogogus* species, as the vectors. This discovery shattered the long-held belief originated by William C. Gorgas that yellow fever could be eradicated by temporary control measures against *Aedes aegypti* in urban areas. The fact of the existence of a permanent reservoir of yellow fever virus in the jungles meant that urban areas were vulnerable to yellow fever epidemics so long as *Aedes aegypti* were present to transmit the virus from imported jungle-infected cases. It was concluded that the only practical defense against the movement of jungle yellow fever to urban areas was to eliminate or at least to maintain control of the urban vector of yellow fever, *Aedes aegypti.*

In Brazil, where the urban yellow fever threat was most imminent, a revitalized nation-wide *Aedes aegypti* control program was initiated with the assistance of the Rockefeller Foundation in the early 1930's. The program proved so successful that after a number of years, *Aedes aegypti* disappeared from vast areas of the country, and by 1945 the vector was virtually eradicated from Brazil. Neighboring Bolivia, which had conducted a control program concurrently with Brazil, was equally successful in eradicating the vector.

Having achieved eradication, the immediate concerns facing these countries shifted from the problem of preventing epidemics of urban yellow fever to guarding against reinfestation of *Aedes aegypti* from neighboring countries. This was an important consideration since the heavy investment of funds and years of effort which had gone into achieving eradication could be nullified by importation of *Aedes aegypti* eggs, larvae or adults across international boundaries. The realization that no country could long defend itself against reinfestation with infested neighboring countries led to the acceptance of hemisphere vector eradication and the present cooperative, international program which aims to see the end of *Aedes aegypti* in this hemisphere in this decade.

In the United States and its insular possessions, the defense against yellow fever has relied mainly on quarantine measures by the Public Health Service Division of Foreign Quarantine. These measures consist primarily of yellow fever vaccination of man and primates arriving from yellow fever areas, medical examination of suspected cases, disinsectization of aircraft and ships and entomological surveillance of airports and dock areas from Brownsville, Texas, to Georgetown, South Carolina. (Hughes and Porter, 1958)

The fact that there hasn't been a reported case of yellow fever in the U. S. since 1924, nor a major outbreak since the 1905 New Orleans epidemic with nearly 1,000 deaths, attests to the effectiveness of these measures. But probably of greater significance to the protection of the U. S. from yellow fever has been the anti-yellow fever programs carried out by our Latin American neighbors since the turn of the century. These have virtually eliminated urban yellow fever from Latin America and have thereby reduced the risk of yellow fever entering the U. S. in spite of the tremendous rise in the flow of international travel. Had the anti-yellow fever efforts been less diligent in Latin America, the history of yellow fever in the U. S. might have shown more recent and more frequent outbreaks than was actually experienced. The epidemic of dengue fever in Puerto Rico in 1963 with over 30,000 reported cases demonstrates the potential epidemic possibilities of an arbo-virus under favorable conditions of transmission.

Although the U. S. was the last of the member nations of the PAHO to activate a program, there were extensive preparations made prior to 1963. Surveys were conducted to determine the distribution and density of the vector in 1956 (Tinker and Hayes, 1959) and 1962 (Tinker, 1963) and a four year pilot project was carried out at Pensacola, Florida, to develop methods and to determine feasibility of a national program.

THE PROBLEM

Aedes aegypti is a domestic mosquito which, since its importation from Africa many centuries ago, has adapted well to the varying environmental conditions existing in this hemisphere from the southern extreme of its range in Argentina to the northern limits in Tennessee. In the mainland United States indigenous infestations have been found in ten southeastern states and overseas in Puerto Rico, the Virgin Islands, Hawaii and Guam. Except for south Florida, the species prevalence is seasonal in the mainland United States.

Aedes aegypti breeds almost exclusively in small collections of water in cans, buckets, tires and numerous other discarded containers commonly found in accumulations of trash and rubbish on premises, vacant lots, salvage yards and dumps in cities and towns. Because of these habitat preferences, infestations are mainly concentrated in substandard urban areas. In better residential areas common breeding sources are birdbaths, flower vases and plant-rooting containers. Occasionally, infestations are found in natural habitats such as tree holes. In coastal areas infestations may occur in the bilges of fishing and pleasure boats. In Key West, Puerto Rico and the Virgin Islands cisterns and other domestic water storage containers are frequently infested.

In view of the habitat preferences of *Aedes aegypti*, major program emphasis has been placed on the elimination of its breeding places by improving community sanitation. This phase of eradication concentrates on improvement of trash collection services, neighborhood clean up, premises sanitation by property owners and adoption and enforcement of city and county sanitation ordinances. These measures will result in lasting beneficial effects long after eradication is achieved, will shorten the duration of the program and will reduce the usage of insecticide.

Because of the time limitation for achieving eradication, the systematic application of insecticide to breeding places is a necessary part of the total eradication program. The procedure and method adopted for the insecticidal operations on the U. S. mainland were developed in the Pensacola Pilot Project. Briefly, these consist of systematic inspection of all premises and the application of a 1¼ percent DDT emulsion to actual and potential infested premises on a 3-month cycle. In areas of generalized infestation, encompassment or containment spraying is employed. This provides for automatic treatment of all premises in city blocks and those surrounding an infested block. After 3 months the operational area is reinspected premises by premises and residual and break-through infestations are re-treated. Based on the finding of the Pensacola Pilot Project, three to four cycles of inspection and treatment will eliminate all infestations.

The insecticide is applied directly to actual and potential breeding sites and adjacent resting places using truck-mounted power sprayers and hand operated compression sprayers. In Puerto Rico and the Virgin Islands, where there is generalized resistance to DDT, 2½ percent malathion emulsion is used on a 2-month cycle.

In the long-term plan for eradication, a surveillance period lasting 3 years is phased in after the infestations have been eliminated. Surveillance consists of three annual premises inspections made during the season of peak prevalence—the first covering all premises and the second and third covering alternate premises. If no infestations are revealed during the surveillance period, the area is declared free of infestations.

PROGRESS OF WORK DURING 1964

Following the appropriation of funds in October 1963, field operations were activated in late June 1964 after a period of 8 months of preparatory work mainly involving recruitment and procurement of supplies and equipment. Since funding did not permit conducting simultaneous operations throughout all ten infested states, a strategy was adopted of concentrating the effort in the most heavily infested areas followed by a phased expansion into areas and states of lighter infestation.

The program organization consists basically of two administrative entities: (1) the Federal, which, under the PHS, is responsible for the overall planning, direction, procurement and funding of the program, and (2) the State, which, under the terms of a Federal contract, is responsible for providing operational personnel under state merit systems. In each state a director, appointed by the state health department, is responsible for general administrative and policy supervision of the program.

Below the state level, the program is decentralized into operating areas usually encompassing one or more counties. Each area is headed by an area supervisor, a federal employee in charge of a force of state-hired foremen, inspectors and spraymen. These employees are paid from federal funds provided under the contract.

The contract brings the state and local health departments into a direct working relationship with the *Aedes aegypti* Eradication Branch. This is particularly desirable for effective source reduction which requires the support and action of local health departments and county and city governments.

Program Activities in 1964

Field operations in 1964 were organized and implemented in extensive areas of Florida, Texas, Puerto Rico and in all of the American Virgin Islands. Equipment made available for these initial operations consisted of 200 hydraulic sprayers, 300 vehicles, and hand sprayers. Personnel for the program included about 100 federal employees assigned to headquarters and to state and area offices and about 900 contract employees hired by the states.

Before operations, the average index of infestations, based on a sample of a percentage of city blocks positive for *Aedes Aegypti* was 33 percent in Florida, 42 percent in San Antonio, Texas, 83 percent in Puerto Rico, and 82 percent in the Virgin Islands. The results of preliminary post-treatment inspections indicates that these indices are being progressively reduced in the operational areas. For example, in Florida, in one carefully treated area sprayed once with DDT emulsion, a pretreatment index of 75 percent infested blocks was reduced to 3.7 percent 12 weeks after treatment. However, not all areas responded as well to single treatments. Where spraying was not carefully or systematically performed due to inexperienced workers and for other reasons, areas had to be retreated before significant reductions were obtained in the indices.

Problems

Although the initial progress was generally satisfactory, some problems were encountered as follows which were not foreseen in the original planning:

1. Infestations of *Aedes aegypti* were generally more intensive and widespread than had been anticipated, particularly in metropolitan areas. Also, infestations in middle- and upper-class urban districts were more prevalent than had been expected. These findings reflected the widespread rubbish distribution in the cities and the ability of the mosquito to adapt to a wide variety of water-holding containers. An added difficulty was the relatively high frequency of interior infestations and infestations in such natural habitats as bromeliads and tree holes.

2. The staffing of the operational areas with contract personnel was delayed by difficulties in recruiting qualified operational personnel by the states at prevailing salary scales.

3. A surprising problem for an operation with comparatively simple methods was obtaining skilled performance from operational personnel, both spraymen and inspectors. As a result spraying and inspections fell short of acceptable standards during the first few months of the program and made clear the need for improving supervision and intensifying in-service training.

4. The task of breeding source elimination appears to be a larger and more complex problem than anticipated due to the widespread distribution of water-

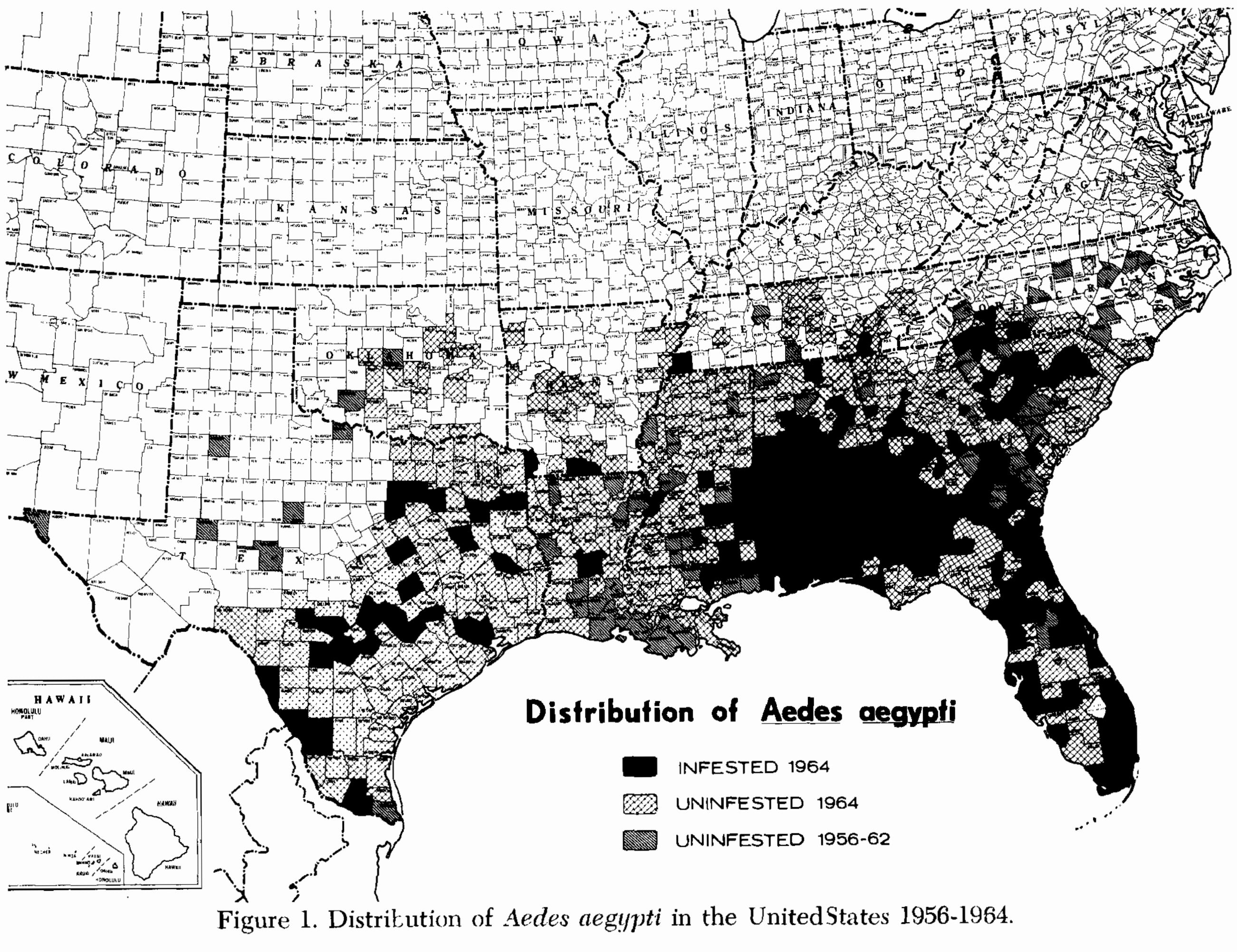


Figure 1. Distribution of *Aedes aegypti* in the United States 1956-1964.

holding containers in commercial and residential areas. The solution will require special effort in the field of public information to secure property owner participation in premises cleanup. Also, forceful health department leadership is needed to secure the cooperation of responsible local agencies and civic groups in developing ways and means of upgrading community sanitation through more effective management of trash, litter, and rubbish collection and disposal.

5. Puerto Rico and the Virgin Islands present special problems not found on the mainland U.S., such as *Aedes aegypti* breeding in cisterns, rain barrels and similar water-supply containers. Resistance of the species to DDT and generalized interior and rural infestations are other problems unique to these islands. Consequently, the Puerto Rico-Virgin Islands plan of operation provides for shorter cycles of premises treatment and inspection and use of malathion insecticide which is effective against DDT-resistant *Aedes aegypti*. A nontoxic deobase Tween-85 insecticide is presently being used for treating cisterns and water barrels. However, compounds of low human toxicity with a longer residual effect than those mentioned are urgently needed.

The problem of *Aedes aegypti* breeding on inter-island boats and vessels must be solved. It will be difficult to prevent reinfestations of *Aedes aegypti*-free areas in Puerto Rico and the Virgin Islands unless adequate preventive measures can be devised.

Although operational problems have received priority attention, there have been encouraging developments, the most significant of which are reported below:

1. The public response to the program has been largely favorable particularly in substandard areas where premises mosquito problems have been alleviated by spraying operations. Despite completion of hundreds of thousands of premises treatments and inspections, relatively few complaints were lodged, some due to spray burning of exotic plants and others by organized opponents to the use of DDT as an insecticide.

2. State, local and federal agencies contacted have responded favorably to requests made for assistance and participation in the program. For example, the Department of Defense has accepted responsibility for eradication on military bases.

3. Recent surveys of Louisiana and Mississippi indicate that there has been a significant recession in the extent of infested areas compared to past years. As a result the program in these states should be less extensive than anticipated from earlier information.

Research and Development

Investigations are in progress to develop more effective and economical methods for eradication. In Puerto Rico and the Virgin Islands, where DDT resistance presents a special problem, new compounds are being tested. Cycle and dosage rates with different insecticides are being field tested and effective and safe methods for eliminating infestations in cisterns and other water-storage containers are being studied. Research and studies by contract with the CDC Savannah laboratory provide for susceptibility testing of field strains of *Aedes aegypti* from operational areas; specification testing of insecticides; equipment and spray-hose testing; evaluation of insecticides as adulticides and larvicides; and testing of lures. Biological control methods are also being considered.

Future Program Considerations

The relatively brief operational experience in 1964 has made plain the need for further applied and basic investigations. Despite the overall adequacy of current operations, improved methods and materials are needed to assure a more effective and economical program under all conditions.

Of equal priority to investigation is training of operational personnel. In contrast to control, eradication demands unusual perfection in the application of techniques and methods. This is necessary to meet planned work schedules on time so that a progressive rate of program expansion continues without interruption or loss of momentum. Only highly-trained, disciplined, and closely-supervised personnel can meet these exacting requirements.

Additional effort in the field of public information is needed to motivate and maintain a high degree of favorable public response to the program and a cooperative attitude toward premises cleanup and community sanitation.

Plans are being developed to intensify and extend the program of source reduction which will be incorporated into regular community sanitation programs. This activity offers the greatest potential for long-range program benefits, since it will reduce the need for spraying work and will contribute to community environmental improvement.

The current plan for expansion of the program calls for initiating operations in all ten infested states in FY 1966 and for programming full-scale activities in 1967 in all areas. Contingent upon the availability of funds and no unforeseen technical or administrative problems, it is predicted that eradication can be achieved early in the next decade.

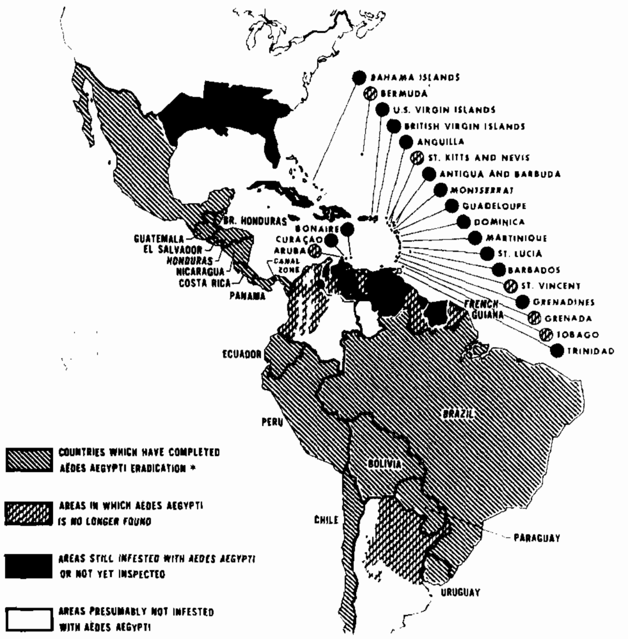
1964 Summary of Mosquito-borne Encephalitides in the United States

In 1964, the incidence of arbo-virus encephalitis in the United States exceeded all past years on record, based on incomplete reports for the year compiled by the Encephalitis Surveillance Unit of CDC. As a part of its surveillance responsibility, this unit collects reports from the states and other information sources on cases of arbo-virus and post-infectious encephalitis. The 1,016 suspect human cases recorded represents the highest annual total reported to the Encephalitis Surveillance Unit since its establishment in 1955. The greatest number prior to 1964 was 625 cases in 1956. In 1963, only 76 cases were reported.

Significantly, there was an extension of the St. Louis virus into the Middle Atlantic region of the country. An outbreak in New Jersey which extended into contiguous areas of Pennsylvania accounted for 120 suspect cases and eight deaths through October. St. Louis virus was isolated from pools of mosquitoes collected in the epidemic area, the first time this virus has been isolated east of the Allegheny Mountains except in Florida.

The largest epidemic of St. Louis encephalitis was in Houston, Texas, where there were 376 cases and 34 deaths—252 of the cases confirmed by laboratory tests. Based on these figures, the overall attack rate was 57.2 per 100,000, with a rate as high as 164.4 per 100,000 in people over age 70. Of the 33 victims who died, 31 were over age 50.

California encephalitis, which has occurred repeatedly in recent years in Wisconsin, always detected among children, was serologically confirmed in three



* ERADICATION CARRIED OUT ACCORDING TO THE STANDARDS ESTABLISHED BY THE PAN AMERICAN HEALTH ORGANIZATION
Prepared by the Pan American Health Organization, 1964
Reprinted with permission by the
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

Figure 2. Status of the *Aedes aegypti* eradication campaign, December 1963.

cases in that state in 1964. Serologic studies showed 10 to 41 percent of persons tested had antibodies to the California encephalitis virus. The first known outbreak of encephalitis due to this virus occurred in Indiana, where ten of a number of suspect cases were confirmed serologically.

During the first 9 months of 1964, 1,157 horse cases of encephalitis were reported, which is less than the 2,426 cases reported for 1963 but more than the number reported for that period of 1963. Again, Western encephalitis accounted for the cases of equine encephalitis west of the Allegheny Mountains, and Eastern encephalitis for the cases in the eastern third of the country. Significantly, the Western virus was isolated from the brain of one horse case in Florida, where some 80 cases of Eastern had been reported through September.

There is no known connection between the large numbers of cases of encephalitis in horses and the large numbers of human cases of St. Louis encephalitis reported in 1964. However, a comparison of data for recent years shows a parallel pattern between the numbers of human cases and the numbers of horse cases of both Western and Eastern encephalitis in the region where each is predominant.

Culex quinquefasciatus, *C. pipiens*, and *C. tarsalis* were the vectors responsible for the 1964 encephalitis outbreaks. 73,000 mosquitoes aspirator-collected in the Houston area were tested in 1,700 pools, and 17 isolations of St. Louis virus were made. This virus was also recovered from the blood of two birds taken in the area. Confirmation of human cases was by serologic testing.

In 1964, several branches of CDC provided technical assistance to state and local health departments in anti-encephalitis activities. The Epidemiology Branch, the *Aedes aegypti* Eradication Branch, and the Technology and Laboratory Branches of CDC all participated in the assistance work as a team effort. In the Houston, Texas, outbreak, the *Aedes aegypti* Eradication Branch loaned power sprayers, vehicles and personnel for emergency mosquito control activities. This assistance was made possible through diversion of manpower and equipment from the ongoing *Aedes aegypti* eradication program currently underway in Texas.

References

Hughes, John H., and John E. Porter. 1958. Measures against yellow fever entry into the United States. **Public Health Reports** 73(12): 1101-06.

Tinker, M. E., and G. R. Hayes. 1959. The 1958 *Aedes aegypti* distribution in the United States. **Mosquito News** 19(2): 73-8.

Tinker, M. E. 1963. The urban nature of *Aedes aegypti*. Proc. N. J. Mosquito Extermination Assoc. 50th: and American Mosquito Control Assoc. 19th: 364-71.

HIGHLIGHTS OF MALARIA ERADICATION WITH THE A. I. D.

EDGAR A. SMITH, *Chief Malaria Advisor*
U.S. Operations Mission to Thailand
Agency for International Development

This is the first time I have been in the United States at the time of the California Mosquito Control Association Conference for nine years. However, having spoken to this Conference for ten years, every year from 1946 to 1956, I still see lots of familiar faces.

Before I show the pictures of Thailand, I want to answer some of the questions people have been asking me the last day or so, to clarify a few things relative to what I have been doing for the past ten years. I am the Chief Malaria Advisor for the National Malaria Eradication program in Thailand. This means that I am an advisor to the Thai Government, to the Ministry of Public Health and the Malaria Eradication Project, on all phases of the malaria program. Most of us in AID are strictly advisors. AID is the Agency for International Development—it's the foreign aid branch of the State Department, and has gone through a series of name changes—starting with Point 4, ECA, TCA, FOA, ICA, now AID. Basically it has been the same organization, even with all the name changes. At the present time AID is directly supporting about twenty malaria eradication programs throughout the world. There are about 85 countries with malaria programs. WHO is working with most of them. WHO and AID are both involved in some of the programs. AID, in direct support of twenty of these programs, provides the commodities—the insecticides, the equipment, training and technical advisors. In the programs WHO works with it provides technical advice and training fellowships. The programs supported commodity-wise in WHO programs are provided with insecticides through the United Nations International Childrens Emergency Fund. These three organizations—WHO, AID and UNICEF, are the only international organizations working with malaria eradication programs throughout the world.

At the present time there are about twelve countries which have successfully eradicated malaria. There are another dozen countries which have eradicated malaria from large areas, and there are others in various stages of progress, some still in a pre-eradication stage.

Many of you have asked me about "malaria control" and I have said that is a dirty word in our field because the emphasis now is on "malaria eradication." The approach is to eradicate malaria—not the mosquito, but malaria. There is little money available for malaria control programs. They have to be eradication programs because both AID and WHO require that they meet the standards for eradication.

Malaria Eradication Programs have four phases:

Preparatory—Locate and number all houses in the affected area, determine the incidence of disease, and decide whether to institute attack phase.

Attack—Spray every surface of each house on which vector mosquitoes may rest after biting. This includes interior walls, undersides of roofs and eaves, and the undersides (tytoons) of houses which stand on stilts. Continue spraying on a predetermined schedule—once a year or twice, depending on local conditions—for three or four years. By this time the transmission chain should be interrupted. When no new cases have occurred among infants for a whole year, pass on to . . .

Consolidation — Discontinue spraying. Visit each home once a month for three years or more and search out everyone suffering from fever. Test their blood, and that of their family and neighbors if malaria is found. Administer radical cure with drugs to all found to have the disease, and follow each case for a year to ensure against recurrence. In case of renewed outbreak, resume attack phase in limited area. When no indigenous cases have occurred for three years, enter . . .

Maintenance—At this point the regular public health service of the nation assumes responsibility for malaria by maintaining vigilance to prevent the disease from gaining a new foothold.

Malaria eradication is the most exacting and difficult public health project the nations of the world have ever attempted. It demands perfection. Every house must be found and sprayed. Every victim must be treated and cured. It requires a large organization with the discipline of an army. It involves problems of transport and supply like those of a military campaign. It costs more at first than malaria control but less in the end, for once malaria is eradicated, vigilance against its reintroduction is carried on by the regular health services.

SECOND SESSION

MONDAY, JANUARY 25, 1:30 P.M.
PHYSICAL EDUCATION BUILDING
UNIVERSITY OF CALIFORNIA, RIVERSIDE

JACK H. KIMBALL, *Presiding*

PANEL: DEVELOPING BALANCED PROGRAMS IN THE UNIVERSITY OF CALIFORNIA FOR MOSQUITO CONTROL

Mr. Kimball: We in the mosquito abatement districts, who have been benefiting from the information and developments that have been coming from the University these many years, have been looking forward to this particular session. I would like to get the session started as quickly as possible because we are all waiting to hear about the latest steps in the University research program. Without further introduction, I would like to present Dr. Maurice L. Peterson, Director of the Agricultural Experiment Station and Dean of Agriculture, University of California, Berkeley. Dr. Peterson.

INTRODUCTION

Dr. Peterson: Thank you. It's always a problem for anyone involved in agricultural administration to really know where problems of agriculture begin and where they end. If you go back into the early days of agricultural research, I think the interpretation of agricultural problems for the most part were confined to problems of production. At some time later in history we became much more concerned with problems of conservation and this became a subject of research. Still later, when economic problems were plaguing us, the whole field of economics became a part of our concern in agriculture. Then, at a later time, there were problems dealing with processing, distribution and marketing. Now, we have problems that relate to the general public and the consumer. I think the division of agricultural science's approach in general has been a rather conservative one. Getting into new fields from time to time, for the most part, has been the result of public demand and usually legislative action which required that the division of agricultural sciences undertake research in certain of these areas. Today it seems that more and more of our problems relate to more and more people living closer and closer together. When we focus our attention on the problem of mosquitoes, I suppose that California has always had mosquito problems, but perhaps it wasn't until the cities began to grow out into the rural areas and mosquitoes started biting people instead of animals that we began to get concerned about this in a big way. Now, because of the urban expansion in these areas, we have such new concerns of agricultural research as flies, mosquitoes, the problem of spray drift, problems of smells, and problems of noises. Things of this kind have had to become part of our concern. They became nuisances, not because agricultural farm operations changed at all but because of the prevalence of many people in these areas.

The division of agricultural sciences has been involved to some extent, but not on a very extensive basis, in the research on mosquitoes for many years. The early work of Stan Freeborn and Stan Bailey, well known to many of you who have been in the field for a long time, became a victim of administration and in recent years has not been as extensive as is called for by the stature of the problem.

About a year ago I decided we needed to bow to the obvious, and arrived at the decision that mosquitoes are an unhappy by-product of agriculture. It was our concern, and we needed to do something about it. I called together the chairmen of the departments of Entomology on the Berkeley, Davis and Riverside campuses, the chairmen of the Department of Biological Control, and the state-wide coordinator on pesticides to consider this problem and what we might do about it.

As a result, each of the chairmen has considered with his own department an expanded program on mosquito control. A document has been prepared, a second committee has been set up in the Agricultural Extension Service to consider an expanded program of mosquito control that will be conducted by Agricultural Extension in cooperation, or in close harmony, with the research work that is contemplated. Now, the preliminary plans that have been drawn up have been presented before the mosquito abatement districts, and have been given to the managers and to the chairmen of the boards of trustees, and I think we've gotten responses back from all of them with many helpful suggestions. It also has gone out to all of the county directors, and the Agricultural Extension Service, again with many good comments coming back as to how the program might be revised and improved. It is going before the committee on insects affecting man, and has been reviewed by the joint committee of the University and the State Department of Public Health. With the revised draft—it is under preparation at the present time – the proposed research program will be reviewed again by the joint committee. This is the proposed expansion program which then will be put in operation, assuming that adequate funds will be provided to carry out the program. If this does come into being, then the results of the research that arise from this effort will be reviewed annually. Certainly, the California Mosquito Control Association will be one of the groups to which those results will be reported and we can assure you that plans for succeeding years will also be considered jointly with the committee between the University and the State Department of Public Health. The program this afternoon, then, as I understand it, is addressing itself to the development of the balanced programs in the University of California on mosquito control. It will reveal some of the thoughts and plans and some of the work that has been done in this general area.

BIOLOGY AND CONTROL OF *HIPPELATES* EYE GNATS

Mir S. Mulla
University of California, Riverside

Laboratory and field studies on the biology and control of eye gnats were pursued during the past year. The aim of these studies was to gain more basic information on the biology of the insects, so that better and more effective means of control can be developed.

Laboratory

Biological Studies—These studies were aimed at getting fundamental information on the gonotropic cycle of eye gnats. Most of the studies were conducted by Mr. T. S. Adams, a graduate student in Entomology.

1. *Survival of Female Eye Gnats at Various Temperatures*—Female *H. collusor* were maintained at 70, 80, 90, 100 and 110°F. and their life span determined. The relative humidity was maintained at 70-80°F. Dim light (4-foot candles of 12 hours daily cycle) was provided by means of small fluorescent tubes.

The time required for 100% mortality of the females at these temperatures was determined to be: 4 days at 110°F., 17 days at 100°F., 25 days at 90°F., 40 days at 80°F. and 80 days at 70°F. This information suggests that eye gnats could survive for long periods at cooler temperatures and that many female eye gnats could overwinter under most southern California conditions. It also provides a basis for the high activity and dense population of gnats at the onset of warm weather in the Coachella Valley.

2. *Influence of temperature on oviposition*—Maximum number of eggs are laid at temperatures of 75-90°F. This is probably due to the long life of the females and the short oogenetic cycle in this range of the temperatures. The maximum peak of oviposition occurs at 80°F. and no eggs are laid at 110°F., since at this temperature the females die before the preoviposition period is over.

Maximum number of eggs/female/day however is obtained at 100°F. At the high temperatures, the ovogenetic cycle is short. Although the females are short lived and do not lay as many eggs as at cooler temperatures, the eggs are laid during a short period of time and therefore the average complement of eggs/female/day is higher. Minimum number of eggs/female/day were obtained at 70°F.

3. *Temperature and Oogenesis*—There are ten stages in the ovogenetic cycle of *H. collusor*. Two important phenomena occur in this cycle. The lag or non-growth phase and growth phase are both influenced by temperature. In the lag phase, stage 2 oocyst of the ovarian cycle persists without further differentiation for some time.

The lag phase is prolonged both at the maximum and minimum threshold temperatures although the duration is much longer at lower temperatures. The duration of this phase at various temperatures is as follows: 340 hours at 60°F., 74 hours at 70°F., 49 hours at 80°F., 34 hours at 90°F., and 38 hours at 100°F. A temperature of 110°F. is lethal to the gnats. Once the 2nd stage oocyst is passed, normal differentiation follows.

The growth phase of the oogenetic cycle is also influenced by temperature. The duration of growth phase at various temperatures is: 90 hours at 70°F., 77 hours at 80°F., 35 hours at 90°F., 33 hours at 100°F. and 36 hours at 105°F., thus showing the shortest growth phase duration to occur at 90 and 100°F.

The period required for completion of successive gonotropic cycles in the females decreases as the number of oogenetic cycles increases. This happens to be the case at all temperatures. For example, the time required for the completion of the first cycle at various temperatures was: 165 hours (70°F.), 125 hours (80°F.) and 95 hours (90°F.); for the second cycle it was: 65 hours (70°F.), 65 hours (80°F.), and 45 hours (90°F.); for the third cycle it was: 55 hours (70°F.), 50 hours (80°F.), and 40 hours (90°F.).

All this biological information points out that *H. collusor* has a high reproductive potential at relatively high temperatures of 85°F. to 95°F.

Mating Age—In earlier studies on chemosterilants, virgin males and females were obtained by getting gnats to emerge from individual pupae placed singly in shell vials. This was a time consuming task and moreover the mortality of the adult population obtained in this manner was quite high. In order to overcome these obstacles, studies were begun to explore the possibility of obtaining virgin males and females from mixed populations emerging in regular laboratory units.

It was determined that males and females isolated from each other, 0, 24 and 48 hours after emergence were virgin. No egg viability was demonstrated for females kept together with the males for a period of 48 hours after their emergence and then isolated from each other for the rest of their lives. Mating between the sexes occurred only after 48 hours after emergence. The extent of mating during the period of 48-72 hours after emergence was not at the maximum level as determined by egg viability. This information on the mating age of *H. collusor* will facilitate easy and complete separation of virgin sexes for chemosterilant as well as genetic studies.

Chemosterilants—Twelve chemicals shown to induce reproductive sterility in a variety of insect species were evaluated against the eye gnat *H. collusor*. The materials were offered either in drinking water or as dry sugar baits to gnats freshly emerged.

In drinking water, the chemosterilant apholate, when offered to mixed population at 1% concentration, produced complete sterility after an exposure period of 24 hours or more. A significant decrease in the number of eggs laid was obtained in the 24-hour exposure period. No eggs were laid in the 48- and 72-hour exposure periods.

Apholate at 0.1% concentration in drinking water, however, induced complete sterility only after an exposure period of 72 hours. There was a significant decrease in the number of eggs laid and hatched in the 24- and 48-hour exposure periods.

Sex specificity of two chemosterilants was studied. The materials were offered as sugar baits to each sex and after pre-determined feeding periods the sexes were reunited in a variety of mating crosses.

Apholate as 0.1% sugar bait formulation induced complete sterility in both males and females during an exposure period of 24 as well as 48 hours. Feeding of the chemosterilant to males crossed with fertile females did not produce much reduction in the number of eggs laid. However, sterile females (fed chemosterilant) mated with fertile males (not offered chemosterilant), laid few or no eggs at all. This type of biological response has been observed to many of the alkylating type chemicals. These findings are in agreement with known biological facts pertaining to reproductive cycle of *Hippelates* eye gnats.

An experimental chemosterilant (U-14743) offered to male gnats at one per cent concentration in sugar bait induced marked reduction in the viability of eggs laid by untreated females mated with the treated males. In a reverse mating cross the number of eggs laid as expected was lower than the previous cross, but the per cent viability was higher. The over-all effect of the two crosses, however, was similar. The degree of sterilization produced in untreated ♂ x treated ♀ and treated ♂ x treated ♀ crosses was essentially the same. For complete sterilization it is obvious that U-14743 may have to be employed at a concentration greater than 1%.

Six experimental compounds as sugar baits were evaluated. Among these, OM-53264 proved toxic at 0.1% concentration, although it produced complete sterility in the surviving individuals. OM-53139 at 0.1% induced complete sterility. The remaining compounds, OM-53061, OM-53247, OM-53362 and OM-53356, caused varying degrees of sterility in the treated population.

Another series of compounds was evaluated as 0.1% and 1.0% sugar baits. U-7726 and U-10071 at the indicated concentrations and 24- and 48-hour feeding periods did not induce any sterility in the treated population. U-14743 turned out to be a promising compound, inducing appreciable sterility at the higher concentration and longer feeding period.

There is one factor which is common to most of the alkylating type chemosterilants. The margin of safety between effective sterilizing concentrations and concentrations producing mortality is very narrow. This problem needs careful study and the most effective concentrations without causing any mortality should be determined.

The development of cultural and larvicidal control measures now makes it possible to reduce eye gnat populations drastically. If and when the equilibrium level of eye gnat populations is lowered, the use of chemosterilants then offers outstanding possibilities to further suppress the gnat populations. Plans of attack to achieve this goal are under consideration now.

FIELD

Soil Larvicides—Soil larvicides can be employed for *Hippelates* control under special types of circumstances. The initial biological and residual activity of 40 compounds was determined in the laboratory; of these 40 materials, only 4 or 5 materials were singled out for field evaluation.

Bayer 37341 was found to give good control of *H. collusor* and *H. hermsi* at the rate of 5 lbs./acre, 2 months after treatment. American Cyanamid 43064, although found to be residual in laboratory studies, did not yield good control of *Hippelates* at 5 lbs./acre, 2 months after treatment. Bayer 29492 produced results similar to American Cyanamid 43064.

Bayer 37289, as in previous studies produced excellent control (97%) of *H. collusor* at 2 lbs./acre, when assessed 2 months after treatment. *H. hermsi* control at this rate and interval was not as good. At the higher rate (5 lbs./acre) this material when assessed 2 months after treatment yielded 99% and 87% control of *H. collusor* and *H. hermsi*, respectively.

A series of special granular formulations of parathion and carbophenothion were evaluated as soil treatments against *Hippelates*. These granular formulations prepared on inert mineral granules and coated with urea-formalin resin to yield slow release of the toxicant were applied at the rate of 5 lbs./acre of actual toxicant and compared with sprays. The parathion granules (5% and 25%) and sprays when assessed 3 months after treatment proved ineffective against *H. collusor*. Control of *H. hermsi* was mediocre with these treatments.

Carbophenothion granules (5% and 25%) and sprays on the other hand as expected produced excellent control of both species when the treatments were assessed for effectiveness 3 months after treatment. The 25% granular formulation produced the highest degree of control (*H. collusor*, 94%, *H. hermsi* 96%), followed by 5% granules (*H. collusor* 85%, *H. hermsi* 94%) and sprays (*H. collusor* 82%, *H. hermsi* 86%). The greater efficiency of granular carbophenothion is noteworthy and this aspect of formulation techniques requires further studies.

Cultural Control Studies—In previous meetings the high effectiveness and practicability of non-cultivation or weed control was reported. However, it was pointed out that non-cultivation measures can be practiced only in certain types of perennial crops such as dates, citrus, apricots and others. This approach for gnat control cannot be practiced in vegetable and field crop fields. Residues of these crops after harvest are usually disked into the soil, which result in heavy eye gnat breeding.

In order to develop a safe and economical means to control eye gnats in these habitats, studies were initiated two years ago. During the earlier studies on the efficacy of petroleum oils as weed killing agents, it was noticed that grounds sprayed with weed oil were rarely frequented with eye gnats. This led to the assumption that certain fractions of the oils repelled eye gnats. To prove this assumption and the weed killing power of the oils, it became necessary to establish a research program to utilize petroleum oils for the control of eye gnats in vegetable and field crops.

The efficacy of herbicidal oils as weed killing agents and/or gnat repellents was studied in natural breeding grounds by making oil applications at intervals prior to disking of the weeds and cover crops into the soil. Repellency of herbicidal oils to eye gnats was also studied by applying the oil to the ground surface immediately after and at intervals after disking.

Herbicidal oils sprayed over the weeds and cover crops, in a citrus grove, 6 days and one day before disking yielded 87% to 95% control of *H. collusor* (pestiferous sp.) and *H. hermsi* (not pestiferous). Oil sprayed over disked ground immediately after tillage produced little control of either species. This treatment of oil has in many other studies produced excellent control of *H. collusor*, but not *H. hermsi*. It is not known as to why the treatment here in citrus grove produced no control of the former species. A treatment made one day after disking as expected produced mediocre control of both species.

In a date garden, oil treatments applied to weeds and cover crops one day, and immediately before disking, produced 99% control of *H. collusor* and 88-95% control of *H. hermsi*. The treatment made immediately after disking yielded 99% control of *H. collusor* but no control of *H. hermsi*. An oil treatment applied one day after disking produced little control of either species. This was the general trend observed in many tests.

In a field where corn stubble was sprayed with herbicidal oil either 7 or 2 days before disking, 98% and 97% control of *H. collusor* was obtained, respectively. Control of *H. hermsi* was 100% and 60%, respectively. The treatment applied immediately after disking of the corn stubble into the soil, as expected, produced 90% control of *H.collusor* and none of *H. hermsi*. Oil treatment made one day after disking gave poor control of *H. collusor* and none of *H. hermsi*. Non-tillage of the corn field yielded 93% control of the former and 71% control of the latter species.

Oil treatments applied to weeds and cover crops in a citrus grove either 6 or 2 days before disking produced 94% to 99% control of both species. However, a treatment made immediately after disking, as expected, gave 93% control of *H. collusor* but none of *H. hermsi*. Oil treatment applied to the ground one day after disking produced poor to no control of both species of gnats.

The pre-disking treatments of herbicidal oils offer greater flexibility and effectiveness for the control of *Hippelates* than the post-disking applications. The latter approach, however, may be utilized under certain sets of conditions.

From the foregoing studies it is apparent that the pre-disking treatments kill the weeds and cover crops and render them unfit as food for gnat larvae. The post-disking treatments on the whole act as repellents against the gnats during a critical oviposition period. That *H. collusor* lays most of its egg complement during the first few hours after disking (see section on oviposition period) lends support to this idea. *H. hermsi* either lays its eggs over long periods after disking or is not repelled by the oil. The repellency of several fractions of the weed oil (Certrex 89) used in these experiments is further borne out by olfactometer studies against *H. collusor* in the following sections.

Oviposition and Emergence Period — During the course of studies on the efficacy of pre- and post-disking treatments with herbicidal oils against *Hippelates*, it became necessary to obtain information on the oviposition period and emergence cycle of eye gnats in the field. Information of this type proved to be of help in explaining the efficacy of post-disking treatment with herbicidal oils.

The oviposition period of *Hippelates collusor* was studied in one citrus grove and 3 date gardens. The breeding sources supporting adequate weeds and cover crop stands were disked thoroughly, usually early in the morning. One square yard emergence cages were set on the freshly tilled soil immediately and at intervals after disking. Cages set immediately after disking would capture gnats developed from eggs laid before disking and those laid during the disking period. Cages set at later intervals would capture gnats from eggs laid as mentioned above and those eggs laid during the period following disking to the time of placement of cages. Horizontal movement of larvae from uncovered ground into the caged area might also contribute somewhat to the total emergence. These studies proved conclusively that *H. collusor* lays most of its eggs within 24 hours after disking of the soil. Due to diversity of the habitat some variation in the oviposition pattern is to be expected.

The emergence pattern of *H. collusor* will depend on climatic and other environmental conditions. During the cooler parts of the year, the gnats were found to emerge over long period of time. In a citrus grove, eye gnats emerged from soil over a period of more than two months during October to December. The peak emergence lasted from 16 to 38 days after disking.

During the warmer weather the gnats in two date gardens were observed to emerge over a period of 3 to 5 weeks, respectively. Peak emergence in one date garden occurred between 16-31 days after disking of the soil. In the other date garden the peak emergence occurred during a period of 16-27 days after disking. The emergence period is further telescoped during the hot season in the Coachella Valley of southern California.

Repellency of Herbicidal Oils—Various fractions of a weed oil (Certrex 89) were studied for their repellency against *H. collusor*, the most predominant and pestiferous species in California.

Six fractions distilling over the range of 370-590°F. were highly repellent. Their repellency was as good as that of ethyl hexanediol, the most effective repellent known thus far against *H. collusor*. Four fractions which distilled over a range of 590-716°F. were not repellent against the gnat. It is apparent that the high boiling fractions with low vapor pressure repelled the gnats very little, if any.

A gross study of the repellency of fractions taken from the top and bottom portions of a refining column was made. A paraffinic-napthenic rich portion from 50% overhead was highly repellent to *H. collusor* in olfactometer studies, while the same type of oil from 50% bottom manifested no repellency. Similarly, aromatic rich portion from the 50% overhead proved to be highly repellent while aromatic rich from the 50% bottom showed no repellency.

In order to find long lasting repellents for personal protection or for exclusion of eye gnats from a given area, further studies have to be carried out. Petroleum oils will provide a good starting point for such studies.

PRELIMINARY FINDINGS CONCERNING THE ADAPTABILITY OF ANNUAL FISHES TO CALIFORNIA MOSQUITO HABITATS

Ernest C. Bay
Department of Biological Control
University of California, Riverside

This is the instant age. We have instant foods, instant light, instant heat, instant shaving cream, and instant aerosol bombs for instant insect control. Unfortunately the latter commodity is seldom an instant solution for most of our instant mosquito problems, particularly for those which occur over such extensive areas as rice fields, temporary reservoirs and irrigated pasture lands. Now it appears that nature may have provided us with an instant predator, a fish, to cope with our instant mosquito enemies, the *Aedes* and the *Psorophora*.

This fish, or rather these fishes as there are several genera and species, belongs to the family of egg laying tooth carps known as Cyprinodontidae. Species which occur native to Africa belong to the genera *Aphyosemion* and *Nothobranchius,* while others which are found in the grasslands of Argentina and Brazil belong mostly to the genus *Cynolebias.* Recently a new genus, *Simpsonichthys,* has been discovered in the highlands of Brazil near the new capital of Brazilia. Here temperatures range throughout the year from a minimum of 40° F. in winter when fish are active during the wet season to a maximum of 98° F. in summer when water is usually absent. At this time the fish survive as eggs beneath sun baked, crusted mud flats.

Here the instant predator aspect of these fish becomes apparent. Just as do the eggs of *Aedes* and *Psorophora* mosquitoes, the eggs of annual fishes hatch within moments of the time when their environment becomes inundated with water after extended dry periods.

Many of you may remember that a few years ago a product known as instant fish appeared for a short time on the national toy market. This item, priced at $2.00 to $3.00, contained a small plastic aquarium, a magnifying glass, a package of brine shrimp eggs (another instant animal), a few salt tablets, and a a small polyethylene packet of peat moss. Within the packet were usually 2 small eggs approximately 2 mm in diameter which, according to the instructions, were to hatch before the buyer's eyes shortly after the packet's contents were immersed in water. If the buyer was lucky, this was so. More often, no fish appeared within hours, days, or even weeks. Hence, the product vanished from the market almost as suddenly as it had appeared.

If the failure of many annual fish eggs to hatch was to the embarrassment of the toy promoters, it is also to our gain in the consideration of these fish as a practical mosquito control. It only reflects one of nature's devices to insure that the species is not tricked into extinction by brief early rainfall or, in our case, accidental wetting. Once conditions are adequate, annual fishes grow rapidly and attain sexual maturity within 6-8 weeks. They then spawn repeatedly until they are eventually destroyed by drought. The eggs of most annual fish species fail to develop while they remain inundated and must be subjected to from 6 weeks to several months of drying before they are ready for hatching by rewetting.

We first learned of instant or annual fish early in our literature survey for candidate natural enemies of midges and mosquitoes, before they were capitalized upon by the toy industry. Unfortunately, such literature as was available implied that most of these species were suited to essentially tropical conditions and required relatively soft, acid water in which to thrive. Rearing was generally recommended over a bed of peat moss. Consequently, at the time the fish were passed over for consideration because it seemed unlikely that they would be adaptable to California conditions.

A more favorable outlook appeared in 1963 when Drs. W. H. Hildemann and R. L. Walford, associate professors in the UCLA School of Medicine, published on "Annual Fishes—Promising Species as Biological Control Agents." While seeking annual fishes in Brazil and Argentina as subjects for gerontology studies, Hildemann and Walford were impressed by their observations that where large mixed populations of annual fishes occurred, mosquitoes were conspicuously absent, but where the fishes were absent due to human waste and interference, mosquitoes were a serious menace.

After reading their article, I contacted Drs. Hildemann and Walford at UCLA and through their cooperation and encouragement I was able to undertake the following field environmental tolerance study with the Argentine pearl fish, *Cynolebias bellottii.* This was one of two fish, the other being *C. elongatus,* that Hildemann and Walford had recommended in their article for field trials in temperate climates such as that of California.

Procedure – Three pairs of *C. bellottii* were placed afield in each of 2 redwood framed dirt reservoirs, each 1-yard square, on August 17, 1964. Within a week a mishap occurred in one reservoir whereby all fish were suddenly killed, believed due to some chemical contaminate in the incoming water. All fish survived in the remaining reservoir until it was emptied by draining on October 18, ending a period of two months' spawning by the fish. During most of the first phase of this study a constant flow, 3 to 8 g.p.m., of irrigation water, pH 8.1-8.2, was maintained through the reservoir at a depth of 4-5 inches. Eventually this flow was curtailed by a float valve to lessen the danger of accidental water contamination. The fish in the reservoir were protected from predators by a tent of 32-mesh saran cloth. They were fed mosquito larvae plus whatever entered with the inflowing water.

At the start of the experiment a bottom partition of 32-mesh saran cloth was buried beneath 2-3 inches of local decomposed granite soil which had been sifted through a 16-mesh sieve. This was done to insure complete and unobstructed sampling of egg-containing soil after the reservoirs were later dried.

Soil samples were taken at intervals of 2 weeks, after drying by coring down to the saran partition, using an inverted plastic container with a lip 72 mm in diameter. Three samples totaling 0.124 square foot were taken on each occasion. Soil moisture determinations were made at each sampling by oven drying

50 grams of soil taken immediately adjacent to each sample site.

Egg-containing soil samples were stored as they were collected, without further drying, in sealed plastic containers until January 18, 1965. They were then washed and the eggs were retrieved for examination and attempted hatching. Except for intermittent rains, all soil samples had been without inundation for three months.

Results: The moisture content of individual soil samples has so far varied from 5.5% to 27.0% by weight, depending on the time when they were taken. Rainfall for the three-month period during which the reservoir has been drained has occurred on 11 occasions and amounted to a total of 2.02 inches. The longest single interval to occur without rain was 30 days, between November 18 and December 18, 1964. Soil moisture on December 7 averaged 10.6%

Twenty-four samples have been taken to date and have averaged 9.2 *Cynolebias* eggs each, with a range of from 1 to 33 eggs per core. It is thereby estimated that the 3 female *C. bellottii* deposited a total of nearly 2,000 eggs during two months.

Of 50 eggs retrieved from samples collected on October 30, 56% were classified as "ripe," due to the presence of mature embryos and of these 70% or 19 fish, hatched within 24 hours. Four of the eggs hatched within the first hour when they were inundated on January 18, 1965.

Unripe but viable eggs are characterized by being clear except for oil vacuoles. Nonviable eggs are usually milky white. The ratio of ripe to clear viable eggs collected on November 10 was 50:50 on January 18 and only 2 fish, or 12% of the ripe eggs, hatched within 24 hours. Although later collections contained numerous apparently ripe eggs, none of these hatched during the January 18 immersion. After 24-hour immersion in water, all unripe or unhatched eggs were redried and stored for further conditioning.

Conclusion — For the present we have discovered that some annual fishes, contrary to earlier published reports, are able to thrive and reproduce under conditions considerably alien to those found in their native habitat. *Cynolebias bellottii* has not only been demonstrated to tolerate relatively hard alkaline (pH 8.4) water, but it has also succeeded well in depositing its eggs in harsh, abrasive, decomposed granite soil. Furthermore these eggs have later withstood storage, retrieval, and handling in this soil. There is now promise that other eggs will continue to survive until a field hatch is attempted late in the spring.

The adult fish seem to be hardy with respect to temperature and disease and results have been sufficiently encouraging that we plan soon to enlarge our studies to include other species of annual fishes. In summary, and in addition, the following characteristics possessed by these remarkable fishes contribute to their attractiveness as mosquito control prospects in appropriate situations:

1. Annual fishes feed voraciously on mosquito larvae from the time they are first hatched.
2. They can survive in situations of impermanent water, such as rice fields and irrigated pastures, where other fish cannot.
3. Most species cannot reproduce or compete with larger fish commonly found in permanent water and consequently annual fish should pose no threat to fisheries' interests.
4. Their eggs do not hatch uniformly so these species are thus protected against accidental extermination.
5. Fully developed ripe eggs can be stored for several months at a time, transported with ease, and have the potential of being applied to mosquito breeding sites as conveniently as chemicals.

It is too early to say, but perhaps one day there will be, in fact, an instant solution for at least a few of our instant mosquito problems.

References Cited

De Carvalho, Saturnio, 1964. The new Brasilia lyrefin. Trop. Fish Hobbyist 10:5-13.

Hildermann, W. H. and R. L. Walford, 1963. Annual fishes-promising species as biological control agents. Jour. Trop. Med. and Hyg. 66: 163-66.

PROGRESS IN MOSQUITO SOURCE REDUCTION IN CALIFORNIA

Richard M. Bohart

Department of Entomology
University of California, Davis

Source reduction for mosquito control as opposed to other temporary means of alleviation of these problems is so obviously desirable that it should probably be classed with motherhood and religion. Why, then, is it not more universally practiced? The answer is threefold: (1) there is still widespread ignorance of its value and its possibilities; (2) it is often complicated from engineering, legal and agricultural aspects; and (3) the initial expense is usually high and subsequent maintenance may be expensive.

The interest of the C.M.C.A. in source reduction is evidenced by the activities of your Source Reduction Committee, and by the fact that many of your annual programs refer to this subject. A rapid survey of the C.M.C.A. Proceedings for the past 10 years shows 24 papers addressed to this theme and many more touching upon it. A perusal of these papers makes it apparent that at least some mosquito abatement districts have been making source reduction a major part of their programs. Problems which lend themselves to this kind of attack, even though there is no single easy solution, include: irrigation of pastures and most agricultural crops, management of dairy drains and city sewage ponds, control of in-city sources of all types, elimination of tree-holes, and the handling of tidal water through drainage and tide gates.

In the 24 papers mentioned above there are a number of specific examples of source reduction applications which have practically or completely eliminated mosquitoes and at the same time saved money for the farmers or food processors involved. However, these papers continually emphasize that even though the general principles are pretty well known, each source reduction job has its complications and peculiarities. Mosquito abatement agency personnel backed up by advice of specialists in the Bureau of Vector Control and the University must be prepared to plan the solution of each major problem on an individual basis. Furthermore, a favorable ratio of cost and expected return over a period of years must be used as a selling point.

The interest of the University of California in these matters has been traditional since H. J. Quayle recommended a type of source reduction for a salt marsh problem in 1906. W. B. Herms, especially in collaboration with H. F. Gray, continued the crusade. In recent years personnel of Agricultural Extension and several Agricultural Departments such as Irrigation, have made substantial contributions to the study of source reduction.

Much of the effort within the University has been of an indirect nature. Examples are the investigations leading to publication of Extension Leaflet 39 by J. B. Dobie, 1958, "Planning a liquid manure system" and Extension Circular 125 by B. J. Jones, *et al.*, 1949, "Irrigated pastures in California." Neither of these mentions mosquitoes, but the principles outlined are entirely applicable to mosquito source reduction. In recent years the importance of including mosquito control in the overall agricultural picture has been increasingly recognized by University people in Extension and in production departments. Consequently, many of the articles originating in counties refer to mosquitoes, as do more general ones, such as Extension Leaflet 131 by D. C. Finfrock *et al.*, 1960, "Water management in rice production," and Extension Circular 504 by C. E. Houston, 1961, "Drainage of irrigated lands." I would like to think that the publication on which I was a co-author may have had something to do with this change in attitude: Extension Circular 439 by S. F. Bailey, R. M. Bohart and L. J. Booher, 1954, "Mosquito control on the farm." In the future we hope to establish a closer liaison between entomologists and specialists in irrigation, soils, agronomy and agricultural engineering, all of whom are interested in efficient agriculture, which in turn results in mosquito source reduction.

In the final analysis the California farmer must be sold on the advantages of source reduction. This will take a concerted effort of research, education and demonstration. It may not be so difficult if we consider that for economic reasons California farmers have installed since 1945 some 5,000 return flow systems and have spent nearly one-quarter billion dollars on land grading.

In conclusion, we are not called upon to decide whether or not we should continue source reduction activities. Considering the inevitable expansion of irrigation facilities in the State together with the continued growth of communities in the foreseeable future, mosquito sources will continue to be created at a rapid rate. Even though we must greatly increase our emphasis on source reduction, we will be fortunate to merely maintain the present level of mosquito control.

AQUATIC MIDGE INVESTIGATIONS IN SOUTHERN CALIFORNIA[1]

Lauren D. Anderson, E. C. Bay and Mir S. Mulla
University of California, Riverside

Aquatic midges of the families Chironomidae and Chaoboridae, although nonbiting, in recent years have been of considerable concern to public health agencies and related organizations, because of the public discomfort which these midges may cause to the people in many communities. This problem is particularly acute in areas of rapid population expansion such as exist in California. The discomfort which these insects cause is the result of the phenomenal numbers in which they occur. They are readily attracted to light, and because of their small size can enter through ordinary window screens. They are easily inhaled and readily fly into the eyes, ears and mouths of people. When food is being served in illuminated areas where midges are abundant it soon becomes contaminated with their bodies. A psychological discomfort is brought about from the fact that midges are very frequently mistaken for mosquitoes. In communities where midge outbreaks are frequent, spider populations increase to where they also reach nuisance proportions within a short time.

The larvae of chironomids are a frequent problem in reservoirs as they tend to be passed into the drinking water of homes and eating establishments. This problem is of current concern to a number of southern California communities, as evidenced by requests for assistance on this problem from the California State Department of Public Health, and from various city water departments.

In addition to the effects of midges on the mental and physical well-being of people in communities, they are also of economic concern in many areas. In residential areas they tend to lessen real estate values. In industrial situations they interfere with the processing of paper, plastics, and food products, and automotive refinishing operations.

Requests for assistance are frequently brought to the attention of the leaders of this project by state and county health departments, mosquito abatement districts, flood control districts, sewage and sanitation departments, and metropolitan water districts.

In view of these facts, this aquatic midge project was actively started in the fall of 1959. During 1959 and 1960, most of the research was carried on in cooperation with the Los Angeles County Flood Control District in 42 experimental ponds established at their Whittier Narrows water spreading grounds. The results of these studies have been summarized in CALIFORNIA VECTOR VIEWS, 1964, 11(3):13-20. In the

[1]These accomplishments have been made possible by the able assistance of Saul Frommer full time, Henry Nakakihara, Kent Hunter, Peter Rauch and Duane Biever part time. Also by financial and personnel assistance from the Los Angeles County Flood Control District, U.S. National Institutes of Health, Los Angeles County Sanitation Districts, California Bureau of Vector Control, various mosquito abatement districts, various city sewage disposal units and city water departments, pesticide companies, California Department of Fish and Game, and many other organizations.

early studies, equipment and techniques were developed for sampling and counting midge larvae and adults. Also, pond control, fish handling and insecticide testing methods were developed. Carp were found to give good control of midge larvae. Dieldrin and DDT gave larval control for about two weeks.

In 1961, with financial aid from the National Institutes of Health grant, the work on this project was expanded and moved primarily to the University of California campus at Riverside. At present, 27 accurately controlled ponds and a well equipped field laboratory are in full operation at U.C.R. (Figure 1). From 1961 to the end of 1964, many detailed taxonomic, life history, nutritional, ecological and other biological studies have been in progress. Also, many pesticide studies on midges and on fish and many biological control studies using various species of fish have been completed. The detailed results of these studies (1961-63) have been presented in the 1961, 1962 and 1963 annual reports of this project and have been made available to you, and will not be repeated here. The 1964 studies are summarized as follows:

Study 1.—Midge-insecticide studies involving 14 materials (20 different formulations) in over 200 tests showed the LD_{50}, in lbs/acre, to be between .02 and .04 for Bayer 29493, GS-13005, Baytex, AC-5216, and parathion; between .07 and .20 for UC-10854, GS-12968, NIA-10242; and at 1 lb/acre practically no control with Bayer 44646, SD-8447, Bayer 39007 and Banol.

Study 2.—A new species of microsporidian disease was found to decimate a heavy larval population (2000/sq. ft. of pond bottom) of *Chironomus californicus* within 20 days of the first appearance of the disease in August. This disease may be the major biotic regulating factor of this midge.

Study 3.—Detailed pond-water-level fluctuation studies (20″ to 6″ for 2-day intervals) indicated little over-all effect on midge population levels, but appeared to change somewhat, the egg deposition pattern.

Study 4.—Three tests on effect of different pond wetting and drying schedules indicated that: A. Fresh filled ponds usually show a 2-4 week midge population boom; B. Drying 2.5 days killed 75% of the midges while 5.5 days' drying killed 100% during July. In cool, damp November, nearly a month's drying was necessary to kill 100% of the larvae; C. Populations returned rapidly in rewet ponds in warm summer months and slowly in cool, late fall and early winter months; D. The time of the year of rewetting ponds appears to influence the species that become dominant more than the length of drying time; E. Drying ponds for variable time intervals but rewetting them all at one time appears to be a better approach to this study than starting drying intervals at the same time and rewetting at different times.

Study 5.—Field and laboratory ecology and biology studies have added materially to our knowledge of the 26 species of midges encountered in this project. An example of this is as follows: The major part of a given population of *Chironomus californicus* was found to emerge within a relatively short period of time (3 to 4 days). This species emerges in the evening within a half-hour period at dusk, and since the pupal stage has been found to be 24 hours or less, a count of pupae during the day gives a good basis for predicting the adult abundance for the evening of the same day.

Study 6.—Field monitoring and identification studies of midges from several areas in California and other parts of the country have contributed materially to understanding this aquatic midge problem.

Study 7.—Taxonomic studies have resulted in a classification key to the species involved in this research. A 45-page manuscript on anatomy of adult Chironomidae is ready for publication.

Study 8.—Fish-pesticides. (A)—In two detailed experiments (47 treatments) malathion was found to be less toxic to *Gambusia* in Palm Springs sewage oxidation basins than in Ontario oxidation ponds or Riverside agricultural irrigation ponds. Differences were not due to the source of fish or the water temperature but appeared to be due to an effect of water chemistry on the pesticide or the fish. (B)—Three laboratory experiments (54 treatments) with malathion on *Gambusia* in temperature control rooms resulted in greatest toxicity at 75° F. and the least at 60° F.; at 40° F. data were variable because temperature was at the minimum tolerance for *Gambusia*. (C)—In 20 field experiments (782 treatments) acute toxicity dosages (LD_{50}) were determined for 37 pesticides on *Gambusia* fish. The LD_{50} in the lbs/acre for most of the materials were as follows: .02 - .10 lbs. for ethyl guthion, methyl ethyl guthion, GS-13005, Bayer 38156, and Diazinon; 0.1 - 1.3 lb. parathion, systox, GS-12968, SD-7597, Bayer 25141, SD-8448, Moricide, and Chipman R-11733; at 1 lb. no kill occurred with SD-8447, and SD-9127; at 2 lbs. little or no kill with Bayer 39007-37344-44646-37289-29493, AC-52160, Dylox, Dexone, Moristan, Banol, Mobil MC-A-600, Sumithion, UC-10854, SD-7438, Bidrin, Sevin, methyl parathion and Baytex.

Study 9.—Midge control with fish. Detailed studies have shown hybrid male *Tilapia*, Asiatic Loach, channel catfish and *Gambusia* mosquito fish to be ineffective in midge control. Annual fish studies have been started and early indications are that they are more effective in mosquito than midge control. For additional data on this midge research see U.C.R. Biological Control Project 2032 report for 1964. In addition to the studies indicated above, additional surveys and control studies have been in progress at Lancaster, Palm Springs, Ontario, Oceanside and San Diego sewage oxidation basins, Lake Elsinore and several city water systems in the southern California area.

Some of the most outstanding accomplishments in this project during the period August 1959 to January 1965 are:

1. The development of practical control procedures involving rotational use of ponds based on the length of the life cycles of the species of midges involved, and on midge larvae survival rates during pond drying intervals. This has been put to practical use in the Whittier Narrows spreading grounds and the Lancaster oxidation basins.

2. The development of methods and procedures of using carp fish for midge larvae control. Carp were used successfully at the Palm Springs oxidation basins

and at Whittier Narrows spreading grounds. Also determining that many species of fish do not give good midge control (*Gambusia,* bass, *Tilapia,* etc.).

3. The testing of hundreds of pesticide formulations on both midge control and toxicity to fish, showed that parathion and several other experimental phosphates (some relatively nontoxic to warm blooded animals) give good midge control and are relatively safe on the fish and other biological organisms. However, with these materials, the control of midges is usually short-lived (2 to 4 weeks).

4. The discovery of a microsporidian disease which shows promise as a biotic regulating factor for *Chironomus californicus.*

5. The development of laboratory methods of mass rearing of several species of midges, heretofore not reared in captivity. Thus, the life cycle has been studied and become known for the first time for several species involved in this problem.

6. Classification keys have been developed and species identification accuracy has been greatly improved during these studies. Over 30 species of Chironomid midges (several new species) have been identified as occurring in this midge complex.

7. Numerous items of equipment and techniques have been developed to greatly facilitate the taking of data in these studies.

The importance and future possibilities of this project are great, and we are sure it will be continued with enthusiasm and vigor for some time to come.

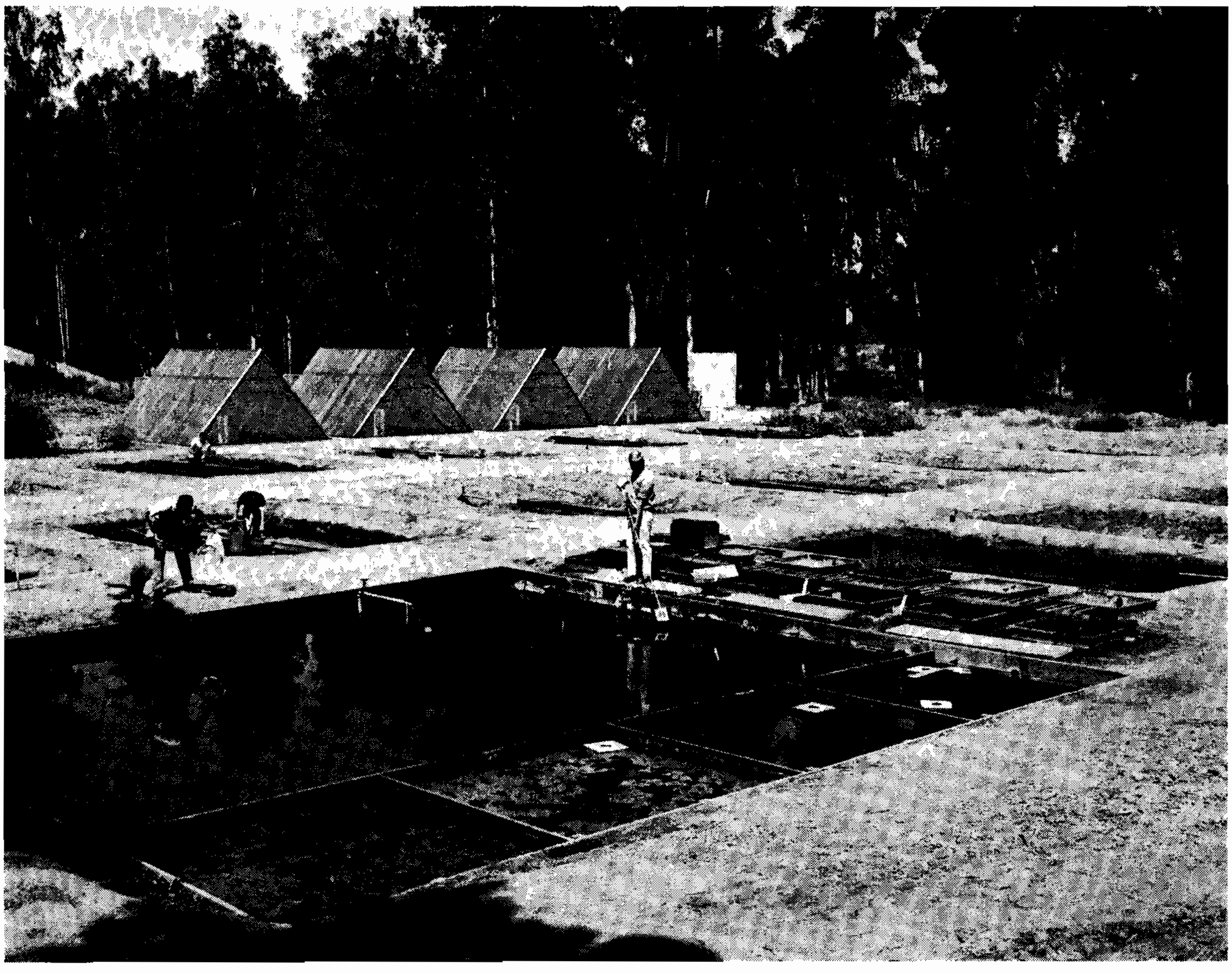


Figure 1. Aquatic midge experimental ponds. The fish ponds are in the foreground, the open biology ponds in the central area, and the screened biology ponds and water filter are in the background.

INSECTICIDE RESISTANCE WITH SPECIAL REFERENCE TO MOSQUITOES

G. P. Georghiou
University of California, Riverside

Of the various subjects which are of concern to entomologists today, perhaps no other has been talked about as much as has the subject of resistance to chemicals. Since 1941, various aspects of this problem have been reviewed in at least 71 different publications; that is 3 reviews per year on the average. There remains little doubt that resistance is the one factor which has had the most profound influence on the orientation of entomological research in recent years. It has been stated very appropriately that the problem of insect control would have been solved had it not been for the question of resistance and the question of residues. And our frantic search for chemosterilants and pheromones might have been a matter of academic curiosity rather than something comparable with the race to the moon. Therefore, resistance *is* of great importance to us, and it directly or indirectly occupies the thoughts or the activities of every entomologist. It is, as a result, a rapidly evolving subject. For these reasons it is desirable that we keep abreast of developments in this field. I shall attempt to provide here a brief outline of the present status of insecticide resistance with special reference to mosquitoes, and to give some of my personal impressions on current trends in research on this subject.

Let me first emphasize the well-known fact that the development of resistance is just one form of microevolution resulting from the selective action of toxicants introduced by man in his environment. As a basic biological phenomenon resistance, therefore, transcends the confines of taxonomic groups to manifest itself in organisms phylogenetically separated from each other for millions of years. This is not surprising, for it is now generally recognized that the very survival and existence of living organisms depends, to a considerable extent, upon their ability to modify chemically an almost unlimited range of compounds following their absorption or ingestion. Many of these compounds, like insecticides, must have been entirely new at one time or another in the evolution of these organisms. It would, therefore, be more surprising if such organisms did not develop resistance than if they did.

As we search through the literature, we come to realize that entomologists are not the only ones who are presently concerned with resistance. The problem is having extremely serious repercussions in microorganisms responsible for human disease. It is also of considerable importance in cancer research, being one of the major obstacles to successful tumor chemotherapy. More than 66 different microorganisms and neoplastic cells are today known to be resistant to one or more of 71 different drugs (Hutchison 1963). Plant pathologists are also beginning to detect cases of resistance in pathogenic fungi, such as resistance to biphenyl by green molds (Harding 1964). In Europe there have been cases of resistance to the anticoagulant warfarin in the common rat (Cuthbert 1963, Lund 1964), and in Australia, rabbits are gradually building resistance to the myxomatosis virus and their numbers are again on the increase (World Health Organization 1965a).

Coming now to insecticides, Table 1 lists the reported cases of insecticide resistance in animals other than insects and mites. It includes frogs and fish, and this information might give some relief to conservationists, although, admittedly this is only a way of getting around the problem.

Let us now look at the statistics concerning the number of insecticide-resistant species of insects and mites. There were only 8 cases of resistance prior to 1940. Since then there has been a steady increase, so that the latest count of published and well documented cases indicates that at least 186 species have by now developed insecticide-resistant strains (Fig. 1). Examination of their taxonomic status (Table 2) shows, as might be expected, that they are not confined to one or a few orders. The many cases of resistance in the Diptera are certainly a reflection of the large number of economically important species in this group, particularly in the genus *Anopheles*.

Our ability to detect resistance has been enhanced in recent years by the coordinating efforts of the World Health Organization (WHO). This organization provides, free of charge, test kits for the detection of re-

Table 1. Insecticide Resistance in Animals

Species	Taxonomic Group	Insecticide	Reference
Argulus sp. (fish louse)	Crustacae, Copepoda	lindane	Lahav et al (1962)
Acris gryllus (southern cricket frog)	Amphibia	aldrin, DDT	Boyd et al (1963) Vinson et al (1963a)
Acris crepitans (northern cricket frog)	Amphibia	aldrin, DDT	Vinson et al (1963a)
Gambusia affinis (mosquito fish)	Pisces	aldrin DDT cyclodienes	Vinson et al (1963b) Vinson et al (1963b) Boyd & Ferguson (1964)
Lepomis macrochirus (blue gill)	Pisces	rotenone	Tompkins (1953)
Mus musculus (white lab. mouse)	Mammalia	DDT	Ozburn & Morrison (1962, 1964)

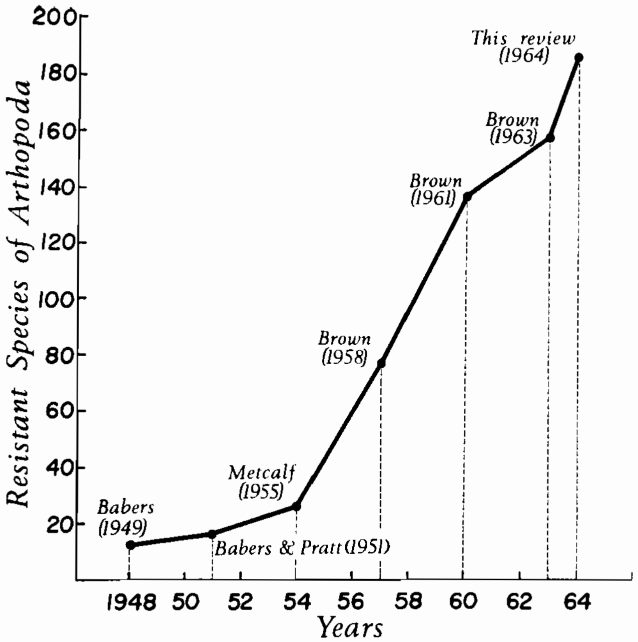


Fig. 1. The progressive increase in number of species of Arthropoda which have developed insecticide-resistant strains.

sistance in various insects and distributes regularly to interested parties an information circular on resistance. A recent publication from WHO (1963) gives detailed instructions on methods for the detection of resistance in 14 different insect groups. Similar efforts with regard to agricultural insects are being made by the F.A.O., the Entomological Society of America (Reynolds 1960, 1962) and by the Canadian Department of Agriculture (Yule 1964). I should also mention the work of Dr. F. O· Morrison (1964) and his co-workers at McGill University, Quebec, toward the development of test kits for the detection of resistance in pests of stored products.

Insecticide Resistance in Mosquitoes—The development, progress, and consequences of resistance have been followed more closely in mosquitoes than in any other group of insects, due undoubtedly to the contribution of the WHO in coordinating research and in distributing information to research workers. It is also a fact that the occurrence of more resistant speces amongst the mosquitoes than amongst any other comparable taxonomic group has been the natural consequence of the intensive and widespread use of insecticides in connection with mosquito control and eradication programs. The two main such programs, the global malaria eradication campaign, directed against vector anophelines, and the eradication of the yellow fever vector, *Aedes aegypti*, in the Americas, have yielded considerable benefits to human health over substantial areas of the world. A report from the WHO for 1963 (WHO 1964) indicates that out of 142 countries recorded as originally having had malarious areas, 48 have wholly or partially eradicated malaria and 33 have eradication programs in the attack and consolidation phase. In terms of population, on December 31, 1964, out of 1560 million people inhabiting the originally malarious areas (not including mainland China, North Korea, and North Viet Nam), 28.5% lived in areas where malaria had been eradicated and 46.4% were covered by eradication programs (WHO 1965b).

The *Aedes aegypti* eradication campaign was begun in the Western hemisphere in 1947, and by the end of 1963 the species had been eradicated from 17 countries and territories (Kerr et al. 1964). Success has been achieved in Mexico, all of Central America and all of South America except part of the Caribbean coast of South America and the Caribbean islands (Pal 1964). In spite of these spectacular successes, however, both programs are facing serious difficulties, and problems are also encountered in the control of *Culex fatigans*, an important vector of filariasis in several countries.

Table 2. Insecticide-resistant species of Arthropoda (1964).

	Economic Importance		*Insecticide Groups*			
INSECTA (insects)	*Agr.*	*Med.-Vet.*	*DDT*	*Dieldrin*	*o-p*	*other*
Orthoptera	----	2	2	2	1	1
Anoplura	----	2	2	1	----	1
Thysanoptera	4	----	2	----	----	2
Heteroptera	4	2	3	5	1	1
Homoptera	20	----	4	4	9	4
Lepidoptera	24	----	16	7	1	3
Coleoptera	19	----	8	14	2	11
Diptera	11	73	49	61	11	2
Siphonaptera	0	5	5	5	----	----
ARACHNIDA (mites, ticks)	12	7	4	6	14	6
CRUSTACEA						
Copepoda	----	1	----	1	----	----
TOTAL	94	92	95	106	39	31

For details on the development of resistance in mosquitoes the reader is referred to a number of earlier comprehensive reviews (Brown 1958, 1961, WHO 1957, 1963). Excellent summaries on the chronological order, distribution, and consequences of development of resistance in anopheline (Ungureanu 1964) and Culicine (Pal 1964) mosquitoes are also available. Here only the highlights of the most recent developments on resistance are presented. For the convenience of the reader, the species with established cases of resistance are listed in Table 3.

Anophelines – Of some 85 described species of *Anopheles*, 34 are reported to have developed resistance to DDT, dieldrin, or to both. One species, *A. nunez-tovari*, has exhibited only DDT resistance, 20 species show only dieldrin resistance while 13 show both types of resistance; six of the latter *(aconitus, albimanus, albitarsis, quadrimaculatus, sacharovi* and *stephensi)* have developed resistance to both insecticides in the same population (Ungureanu 1964) while in the remaining 7 the two types of resistance have so far appeared in geographically separate populations. Fortunately, no cases of resistance to organophosphorus (o-p) compounds have been reported either in laboratory or in field populations of *Anopheles*. This, however, cannot be considered as evidence of lack of o-p resistance potential in this genus. The use of o-p compounds in anopheline environments appears to have been rather limited and no laboratory selections for o-p resistance in anophelines have yet been reported.

The chronological order of appearance of resistance in anophelines is indicated in Fig. 2. The first cases of resistance appeared in 1954 (DDT-resistant *A. sundaicus* in Java, and dieldrin-resistant *A. quadrimaculatus* in Mississippi, Ungureanu 1964), and the number of resistant species has been constantly increasing since. The remarkable increase in cases of dieldrin resistance is in part attributed to the discreteness of such resistance and to the ease of its detection since dieldrin-resistant individuals become practically immune to this insecticide. It also coincides with the extensive distribution of test kits by the WHO for the detection of resistance. Although Fig. 2 shows a gradual decline in reports of new resistant species of *Anopheles*, the situation has by no means been stabilized since the area distribution of resistant populations may be expected to increase as new areas are brought under insecticidal treatment.

Even though the development of resistance usually follows the intensive use of an insecticide in the area, there are some notable cases of failure to develop resistance; for example, in Northern Java and Adana, Turkey, where DDT resistance has appeared in *A. sundaicus* and *A. cacharovi*, respectively, dieldrin has given excellent control for several years. On the other hand, populations of *A. pseudopunctipennis* in Mexico and *A. fluviatilis* in the region of the Arabian Sea, have remained susceptible to DDT for several years but became resistant to dieldrin very soon after its introduction (WHO 1963). The genetic potential for development of dieldrin resistance in *A. albimanus* in Panama is probably low as suggested by the absence of such resistance in spite of the use of this insecticide in that country for several years; surprisingly, this species is resistant to dieldrin in the neighboring

Table 3. Species of mosquitoes with established cases of resistance.[a]

Species	Insecticide groups: DDT	Dieldrin	Organophosphorus
Anopheles aconitus	x	x	
A. albimanus	x	x	
A. albitarsis	x	x	
A. annularis	x	x	
A. aquasalis		x	
A. barbirostris		x	
A. coustani		x	
A. crucians		x	
A. culicifacies	x	x	
A. filipinae		x	
A. fluviatilis		x	
A. funestus		x	
A. gambiae		x	
A. labranchiae		x	
A. labranchiae atroparvus		x	
A. maculipennis		x	
A. messeae		x	
A. minimus flavirostris		x	
A. neomaculipalpus		x	
A. nunez-tovari	x		
A. pharoensis	x	x	
A. pseudopunctipennis	x	x	
A. pulcherrimus		x	
A. quadrimaculatus	x	x	
A. rangeli		x	
A. sacharovi	x	x	
A. sergenti		x	
A. splendidus		x	
A. stephensi	x	x	
A. strodei	x	x	
A. subpictus	x	x	
A. triannulatus		x	
A. sundaicus	x	x	
A. vagus		x	
Aedes aegypti	x	x	x
A. cantans	x		
A. cantator	x	x	
A. detritus	x		
A. fijiensis	x		
A. melanimon (=dorsalis)	x	x	x
A. nigromaculis	x	x	x
A. poicilius	x		
A. sollicitans	x	x	x
A. taeniorhynchus	x	x	x
A. vexans	x		
Culex coronator	x		
C. erythrothoras	x		
C. molestus	x	x	
C. pipiens pallens	x	x	
C. pipiens pipiens	x	x	
C. pipiens quinquefasciatus (=fatigans)	x	x	x
C. peus	x		
C. restuans		x	
C. salinarius		x	
C. tarsalis	x	x	x
C. tritaeniorhynchus	x	x	
Psorophora confinnis		x	
P. discolor		x	

a/ In compiling this list the author has made use of a number of reviews and would be remiss not to acknowledge his indebtedness. Reviews utilized include those of Brown (1961, 1963), Hoskins (1963), Pal (1964), and Ungureanu (1964).

Guatemala, El Salvador, Honduras, and Nicaragua (Ungureanu 1964). At the other extreme, a population of *A. funestus* in an unsprayed area of Northern Nigeria was reported to be composed of 53% susceptible and 47% hybrid and resistant individuals with respect to dieldrin (Service 1964). A similar phenomenon was also found in *A. gambiae* (Service and Davidson 1964). Indeed, the latter species has shown such high propensity to develop resistance to dieldrin that this insecticide became useless in West Africa before malaria eradication could be formally undertaken (Ungureanu 1964).

As in the case of resistance in houseflies, so in mosquitoes resistance to dieldrin involves an almost complete lack of effectiveness of this compound. In contrast, DDT continues to kill DDT-resistant mosquitoes if the dosages are increased. It has recently been demonstrated (Davidson 1963, 1963b) that the genetic mechanisms responsible for DDT and dieldrin resistance in several species of *Anopheles* are entirely independent, so that when resistance to one compound appears in a population, it is possible to change to the other compound and still obtain control for some time. Only when resistance to both compounds (double resistance) is present in the same population, serious operational difficulties may arise. Such is especially the case with *A. stephensi* in southern Iran, and *A. aconitus* in central Java. (WHO 1963, Ungureanu 1964. In certain areas, it has been possible to obtain satisfactory control for a short time by increasing the rate of applictaion of DDT to 2 g/m^2.

The serious difficulties created by the appearance of double resistance has prompted extensive research into new insecticides. Two promising organophosphorus insecticides, malathion and dichlorvos, were tested for their effectiveness in interrupting malaria transmission in large-scale field trials in Africa during 1963. The former performed satisfactorily and is considered ready for use in malaria eradication (WHO 1965b). The latter, however, appeared to be unsuccessful in interrupting malaria transmission (Foll and Pant 1964) owing mainly to its volatility and the high degree of ventilation of the test houses (WHO 1964, 1965b).

Culicines—Several species of culicine mosquitoes present especially serious problems because of their ability to act as vectors of filariasis, yellow fever, haemorrhagic fever, and other serious diseases, and for their ability to readily develop resistance to insecticides; the latter fact is further aided by the presence of various species in agricultural environments so that they are inadvertently subjected to insecticidal selection pressure. Table 3 lists 11 species of *Aedes*, 11 of *Culex* and 2 of *Psorophora* resistant to insecticides, and Fig. 2 indicates the progressive increase in the number of species resistant to DDT, dieldrin or o-p compounds.

Aedes aegypti is normally very susceptible to DDT (LC_{50} 0.005 ppm. for larvae, Khan and Brown 1961) and as mentioned earlier, it has been possible to eradicate this species from a wide area of its distribution in the western hemisphere. However, DDT resistance has been reported in 11 countries of the Caribbean area and in southern Viet-Nam, southern Florida, Fiji and Japan (WHO 1963). More recently, it was reported that several islands of the Caribbean from which *A. aegypti* had been eradicated have been reinfested (Pal 1964) and that resistance to DDT and dieldrin is now widespread over the entire area (Kerr et al. 1964). In addition, o-p resistance (diazinon, malathion and trichlorofon) have been reported in Puerto Rico (Fox and Garcia 1961) and a recent survey indicates incipient tolerance to malathion, diazinon and possibly to fenthion in several other areas of the Caribbean (Kerr et al. 1964). This situation casts serious doubts as to the feasibility or bringing the *A. aegypti* eradication campaign in the western hemisphere to a successful conclusion by the set deadline of 1966 (WHO 1964).

The most extensive development of o-p resistance in mosquitoes has been noted in the irrigation-water mosquito *Aedes nigromaculis* in the Central Valley of California. This species had developed resistance to chlorinated hydrocarbon insecticides by 1951 (Gjullin and Peters 1952) and has since then been controlled with o-p compounds. In addition, the species is subjected to selection pressure by various agricultural insecticides over most of its ecological environment. Resistance to parathion appeared in 1958 (Lewallen and Brawley 1958). Substitution of methyl parathion

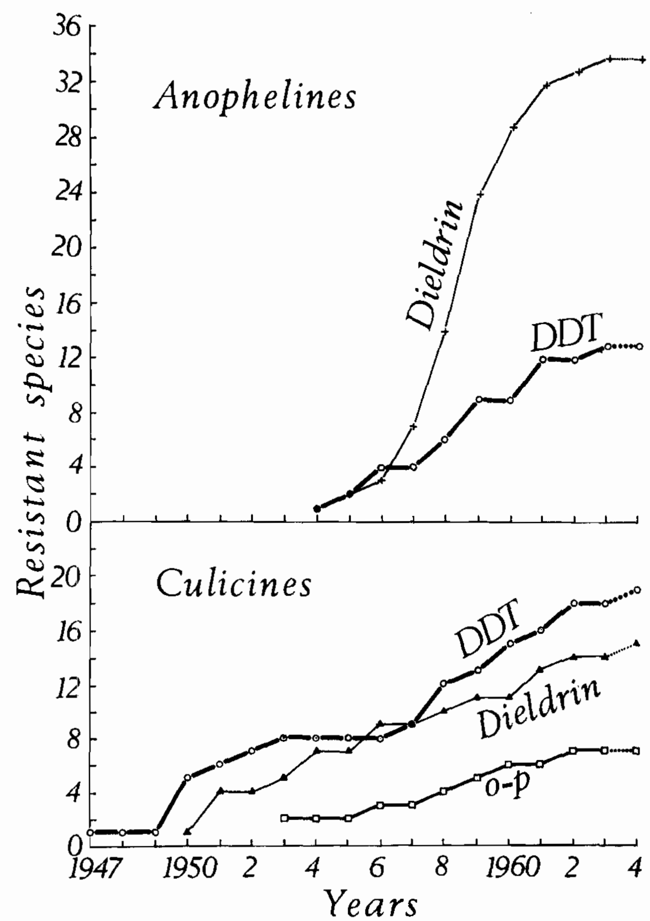


Fig. 2. Chronological order of appearance of insecticide resistance in anopheline and culicine mosquitoes.

for parathion was initially successful but was followed by control failures in 1962 (Brown et al. 1963). In an extensive survey of o-p resistance in this species, Brown et al. (1963) found that the resistance levels varied over the area of the Valley, reaching astonishingly maximum values of 4000X to parathion, 20X to methyl parathion and fenthion, and 10X to malathion. By examining the cross-resistance spectra in different sampled areas they concluded that o-p resistance in this species is nonspecific and that it is inducible by any one of the four compounds tested. Whether this may be a case of multiple o-p resistance as a result of the large variety of o-p compounds used over the area of distribution of the species must be determined by a detailed genetical and biochemical study of resistance in this population. Unfortunately, the laboratory colonization of this species has not yet been achieved.

DDT and dieldrin resistance in *Culex pipiens quinquefasciatus* (fatigans) presents especially serious problems in the antifilariasis program in India (WHO 1963). This species is naturally tolerant of DDT in the adult stage (LC_{50} 6.9 ug/cm^2, Georghiou and Metcalf 1961) although susceptible to it in the larval stage (LC_{50} 0.01-0.07 p.p.m.). However, the development of DDT resistance renders both stages highly resistant to this insecticide. Pal (1964) indicates that DDT-resistant strains of this species have been reported from 30 countries and dieldrin-resistant strains from 24 countries. The resistant strains are generally susceptible to o-p compounds but resistance to the latter has been reported from at least three countries: the use of malathion as a larvicide in the Cameroun has induced moderate resistance to malathion and diazinon (LC_{50} 1.8 and 1.65 ppm, respectively) (Mouchet et al. 1960); larvicidal treatments with malathion induced moderate malathion resistance (2-5X) and high diazinon resistance (70X) in Sierra Leone (Thomas 1963 in Mouchet 1964); similar results were obtained from diazinon pressure, indicating cross resistance between malathion and diazinon in this species. Interestingly enough, o-p resistance regressed to normal susceptibility three years after suspension of further treatments (Mouchet 1964). Finally, moderate malathion resistance in this species was reported in California (Lewallen 1961).

The Character of Resistance—Now that we have seen where we stand with resistance in mosquitoes, let us look at the character of resistance as such. What makes an insect resistant to an insecticide? Resistance may be of two kinds: physiological and behavioristic. In the first category we include the cases where the insect survives direct contact with the insecticide. This is usually brought about by various mechanisms, such as reduced rates of absorption, enhanced excretion, or inert storage of the toxicant in the body fat. However, by far the most important mechanism of physiological resistance is that of degradation of the insecticide by means of certain enzymes. Such enzymes have been shown to be responsible for DDT, malathion and diazinon degradation, and it is now certain that resistance to carbamates is also due to specific enzymes. On the other hand, the exact mechanism of resistance to dieldrin continues to elude the efforts of many serious investigators. It has been hypothesized that the primary mechanism for such resistance is one of increased insensitivity to the presence of the toxicant within the insect's body. Recently, however, Oonnithan and Miskus (1964) presented evidence of metabolism of dieldrin in *Culex pipiens quinquefasciatus.*

The second type of resistance, the behavioristic type, is due to a tendency of the insect to avoid prolonged contact with the insecticide. For instance several species of *Anopheles* may be irritated by contact with DDT so that they leave the surface before picking up a lethal dose.

Behavioristic resistance in houseflies, specific toward malathion, has been reported from Georgia (Kilpatrick and Schoof 1958, Fay et al. 1958, Schmidt and LaBrecque 1959). Whereas at the beginning, malathion-sugar baits attracted flies readily, when control failures were observed it was found that the majority of flies approached the bait in flight but failed to alight on it. These same populations showed no aversion to landing and feeding on trichlorofon or dichlorvos baits. The feasibility of selecting for behavioristic resistance to insecticides has recently been demonstrated in the laboratory with houseflies (Smith and Yearian 1964) and also with the mosquito *Anopheles atroparvus* (Gerold and Laarman 1964).

I should indicate at this point that recent emphasis on the genetic aspects of resistance has been invaluable in the study of this problem. In addition to elucidating the genetic relationship of the various types of resistance, such studies also provide the biochemist with genetically defined material for comparative studies on the factors responsible for resistance. For recent reviews see Davidson and Mason (1963), Oppenoorth (1965) and Georghiou (1965).

Countermeasures for Resistance—Let us now see what research is doing to counteract the phenomenon of insecticide resistance. I believe that the elucidation of physiological processes involved in resistance is of tremendous value in devising rational countermeasures. For example, if resistance is due to a specific detoxication enzyme then the addition of an enzyme inhibitor to the formulation could restore for some time the effectiveness of the insecticide. This has been demonstrated by the fact that the addition of the so-called WARF antiresistant (*N,N*-di-*n*-butyl-*p*-chlorobenzenesulfonamide) to DDT restores to some extent the effectiveness of the latter against various DDT-resistant insects. When tested against DDT-resistant *Aedes aegypti* at 1:1 ratio with DDT, the antiresistant decreased the LC_{50} levels of resistance to DDT by 6 to 60 times and its amyl analog reduced them by 2 to 30 times; the synergistic effect was negligible with susceptible strains (Pillai et al. 1963). However, in field trials against DDT-resistant *Culex pipiens quinquefasciatus,* the antiresistant produced no significant increase in the toxicity of DDT. Even at a rate of 1.25 lb. per acre, which is in excess of that normally applied, the combination gave only 85% control. (Lewallen 1963). In spite of the initially promising results on *Aedes aegypti,* it was soon found that resistance to the DDT-antiresistant combination could be developed through selective pressure in the laboratory (Pillai et al. 1963). In Riverside, we have shown that houseflies can become extremely resistant to certain carbamates (Georghiou et al. 1961). However, the addition of the nontoxic compound piperonyl butoxide to the carbamate formulation restores its effectiveness against carbamate-resistant flies (Moorfield 1958, Georghiou 1962). Only moderate resistance to the mixture has been observed so far.

Similarly, a knowledge of the mechanism of resistance toward a particular insecticide is often utilized in the synthesis of compounds which are less likely to be sensitive to that particular mechanism. It has been shown, for example, that a slight modification in the DDT molecule by the substitution of a hydrogen atom by a deuterium atom restores the effectiveness of the insecticide against DDT-resistant *Aedes aegypti* (Pillai et al. 1963b). However, the deuterated analog of DDT is not effective against DDT-resistant strains of the housefly. Similarly *o*-chloro-DDT is not appreciably affected by housefly DDT-dehydrochlorinase, probably due to steric hindrance (Hennessy et al. 1961), but is readily affected by *Aedes aegypti* DDT-dehydrochlorinase (Kimura and Brown 1964). In another case, replacement of the carboethoxy group in malathion by carbomethoxy resulted in abolishment of the 60-fold resistance to malathion in *Culex tarsalis* (Dauterman and Matsumura 1962) due to specificity of the carboxyesterase enzyme involved in resistance.

It has also been demonstrated that if the synthesis of a defensive enzyme is at the expense of an existing enzyme, such as an ali-esterase, then the insect which bcomes resistant to one insecticide might also become more susceptible to another. This is the phenomenon of negative correlation which has greatly influenced the screening programs for new insecticides. The only well-documented such case concerns strains of *Drosophila* in Japan, in which resistance to phenylourea, DDT, BHC, organophosphates, and carbaryl is accompanied by greater susceptibility to phenylthiourea and vice versa (Ogita 1958, 1961a, 1961b, 1964). This, however, does not apply to houseflies. In another case it was observed that resistance to dieldrin in *Anopheles albimanus* was lost almost entirely after selection by the carbamate AC 5727 while it remained unaffected in the unselected control strain (Georghiou and Metcalf 1963). This, and other cases in the literature must await further clarification by means of appropriate genetic tests before they can qualify as true instances of negatively correlated toxicity.

The problem of resistance has also had the beneficial effect of stimulating greater wisdom in the use of established insecticides, as exemplified by the concept of integrated control. It also has prompted the search for new methods of insect control, such as the use of insect pathogens, chemosterilants, pheromones or of genetic control. However plausible these new methods may be, and they undoubtedly are, they do not obviate the need for insecticides. Chemosterilants have limitations because of their high toxicity and the hazards inherent in their mode of action. Similarly, the isolation and synthesis of pheromones requires prolonged and tedious experimentation. It is also of interest to note that these novel methods of control do not appear to be free of the problems of resistance. Laboratory work has shown that resistance to *Bacillus thuringiensis* can be developed in the housefly (Harvey and Howell 1965), and also that the mosquito *Aedes aegypti* can be selected for low levels of resistance to the chemosterilant apholate (Hazard et al. 1964). Similarly, radiation resistance is known in various animals including *Drosophila melanogaster* (Ogaki and Tanaka 1963).

It may, therefore, be concluded that although considerable advances have been made in research on resistance and on countermeasures for it, the phenomenon of resistance will remain as a challenge for many years to come.

References Cited

Boyd, C. E., S. B. Vinson, and D. E. Ferguson. 1963. Possible DDT resistance in two species of frogs. Copeia 1963 (2): 426-29.

Boyd, C. D. and D. E. Ferguson. 1964. Susceptibility and resistance of mosquito fish to several insecticides. Jour. Econ. Entomol. 57(4):430-31.

Brown, A. W. A. 1958. Insecticide Resistance in Arthropods. World Health Organization, Monograph Series No. 38, 240 p.

Brown, A. W. A. 1961. The challenge of insecticide resistance. Bull. Ent. Soc. Amer. 7(1):6-19.

Brown, A. W. A. 1963-64. Insect Resistance. Farm Chemicals 126(10):21; 127(1):58.

Brown, A. W. A., L. L. Lewallen, and P. A. Gillies. 1963. Organophosphorus resistance in *Aedes nigromaculis* in California. **Mosquito News** 23(4):342-45.

Cuthbert, J. H. 1963. Further evidence of resistance to warfarin in the rat. Nature 198:807-8.

Dauterman, W. C., and F. Matsumura. 1962. Effect of malathion analogs upon resistant and susceptible *Culex tarsalis* mosquitoes. Science 138:694-5.

Davidson, G. 1963a. DDT-resistance and dieldrin-resistance in *Anopheles albimanus*. Bull. Wld. Hlth. Org. 28:25-33.

Davidson, G. 1963b. DDT-resistance and dieldrin-resistance in *Aopheles quadrimaculatus*. Bull. Wld. Hlth. Org. 29:177-84.

Davidson, G. and G. F. Mason. 1963. Genetics of Mosquitoes. Ann. Rev. Ent. 8:177-96.

Fay, R. W., J. W. Kilpatrick, and G. C. Morris, III. 1958. Malathion resistance studies on the housefly. Jour. Econ. Entomol. 51(4):452-3.

Foll, C. V., and C. P. Pant. 1964. A large-scale field trial with dichlorvos as a residual fumigant insecticide in Kankiya district, Northern Nigeria. W.H.O./Vector Control/70 41 p.

Fox, I., and I. Garcia-Moll. 1961. Multi-resistant *Aedes aegypti* in Puerto Rico and Virgin Islands. Science 133:646-47.

Georghiou, G. P. 1962. Carbamate Insecticides: Toxic action of synergized carbamates against twelve resistant strains of the housefly. Jour. Econ. Entomol. 55(5):768-72.

Georghiou, G. P. 1965. Genetic Studies on Insecticide Resistance. Advances Pest Control Research (In Press).

Georghiou, G. P., and R. L. Metcalf. 1961. Carbamate insecticides as potential mosquito control agents **Mosquito News** 21(4):303-6.

Georghiou, G. P., and R. L. Metcalf. 1963. Dieldrin susceptibility: Partial restoration in *Anopheles* selected with a carbamate. Science 140:301-2.

Georghiou, G. P., R. L. Metcalf, and R. B. March. 1961. The development and characterization of resistance to carbamate insecticides in the housefly. Jour. Econ. Entomol. 54(1):132-40.

Gerold, J. L., and J. J. Laarman. 1964. Selection of some strains of *Anopheles atroparvus* with different behavioral responses to contact with DDT. Nature 204:500-1.

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

Harding, P. R., Jr. 1964. Assaying for biphenyl resistance in *Penicillium digitatum* in California lemon packing houses. Plant Disease Reptr. 48(1):43-46.

Harvey, T. L., and D. E. Howell. 1965. Resistance of the housefly to *Bacillus thuringiensis* Berliner. Jour. Invertebrate Pathol. 7(1):92-100.

Hazard, E. I., C. S. Lofgren, D. B. Woodard, H. R. Ford, and B. M. Glancey. 1964. Resistance to the chemical sterilant apholate in *Aedes aegypti* Science 145:500-1.

Hennessy, D. J., J. Fratantoni, J. Hartigan, H. M. Moorfield, and M. H. J. Weiden. 1961. Toxicity of 2-(2-halogen-4-chlorophenyl)-2(4-chlorophenyl)-1, 1, 1-trichloroethanes to normal and DDT-resistant houseflies. Nature 190-341.

Hoskins, W. M. 1963. Resistance to Insecticides. Interntl. Rev. Trop. Med. 2:119-74.
Hutchison, D. J. 1963. Cross resistance and collateral sensitivity studies in cancer chemotherapy. Adv. Cancer Res. 7:235-350.
Kerr, J A., S. deCamargo, and Z. H. Abedi. 1964. Eradication of *Aedes aegypti* in Latin America. **Mosquito News** 24(3): 276-82.
Khan, N. H., and A. W. A. Brown. 1961. Genetical studies on dieldrin resistance in *Aedes aegypti* and its cross-resistance to DDT. Bull. Wld. Hlth. Org. 24:519-26.
Kilpatrick, J. W., and H. F. Schoof. 1958. A field strain of malathion-resistant houseflies. Jour Econ. Ent. 51(1):18-19.
Kimura, T., and A. W. A. Brown. 1964. DDT-dehydrochlorinase in *Aedes aegypti*. Jour. Econ Ent. 57(5):710-16.
Lahav, M., Shilo, and S. Sarig. 1962. Development of resistance to lindane in *Argulus* populations of fish ponds. Bamidgeh 14(4):67-76.
Lewallen, L. L., and J. H. Brawley. 1958. Parathion-resistant *Aedes nigromaculis* Calif. Vector Views 5:56.
Lewallen, L. L. 1961. Insecticide-resistant mosquitoes in California 1949-61. **Mosquito News** 21(4):310-15.
Lund, M. 1964. Resistance to warfarin in the common rat. W.H.O. Inf. Circ. on Vector Control 2:15.
Moorfield, H. H. 1958. Synergism of the carbamate insecticides. Contribs. Boyce Thompson Inst. 19(6):501-8.
Morrison, F. O., and V. Kumar. 1964. Susceptibility levels of stored product pests to present-day insecticides. Insect Toxicologists' Inf. Service, Wageningen, Netherlands 7:121.
Mouchet, J. 1964. Résistance de *Culex pipiens fatigans* Wied. aux insecticides organophosphorés. W.H.O. Vector Control 82, 5 p.
Mouchet, J., R. Elliott, J. Garion, J. Voelckel and J. Varrieras. 1960. La résistance aux insecticides chez *Culex pipiens fatigans* Wied. et les problèmes d'hygiène urbaine au Cameroun. Médecine Tropicale 20(4):447-56.
Ogaki, M., and E. Tanaka. 1963. Inheritance of Tolerance to Gamma Radiation in *Drosophila melanogaster*. Genetics 48:904.
Ogita, Z. 1958. The genetical relation between resistance to insecticides in general and that to phenylthiourea (PTU) and phenylourea (PU) in *Drosophila melanogaster*. Botyu-Kagaku 23(4):188-205.
Ogita, Z. 1961a. An attempt to reduce and increase insecticide-resistance in *D. melanogaster* by selection pressure. Botyu-Kagaku 26(1):7-18.
Ogita, Z. 1961b. Genetical studies on action of mixed insecticides with negatively correlated substances. Botyu-Kagaku 26(3):88-93.
Ogita, Z. 1964. Negatively correlated cross-resistance in *D. melanogaster*. Jap. Jour. of Med. Science and Biol. 17(1):54-57.
Oonnithan, E. S., and R. Miskus. 1965. Metabolism of C^{14}-dieldrin by dieldrin-resistant *Culex pipiens quinquefasciatus* mosquitoes. Jour Econ. Entomol. 57(4):425-26.
Oppenoorth, F. J. 1965. Biochemical Genetics of Insecticide Resistance. Ann. Rev. Entomol. 10:185-206.
Ozburn, G. W., and F. O. Morrison. 1962. Development of a DDT-tolerant strain of laboratory mice. Nature 196:1009-10.
Ozburn, G. W., and F. O. Morrison. 1964. The selection of a DDT-tolerant strain of mice and some characteristics of that strain. Canadian Jour. Zool. 42(4):519-26.
Pal, R. 1964. Practical implications of insecticide resistance in Culicine mosquitoes. W.H.O./Vector Control/88, 11 p.
Pillai, M. K. K., Z. H. Abedi, and A. W. A. Brown. 1963a. WARF antiresistant compounds as synergists against DDT-resistant *Aedes aegypti*. **Mosquito News** 23(2):112-17.
Pillai, M. K. K., D. J. Hennessy, and A. W. A. Brown. 1963b. Deuterated analogues as remedial insecticides against DDT-resistant *Aedes aegypti*. **Mosquito News** 23(2):118-25.
Reynolds, H. T. 1960. Establishing levels of insecticide resistance with standardized laboratory detection methods in agricultural arthropod pests. Ent. Soc. Amer. Misc. Publ. 2(1):103-11.
Reynolds, H. T. 1962. Standardized laboratory detection methods for resistance determination in agricultural arthropod pests. Bull. Ent. Soc. Amer. 8(1):9-14.
Schmidt, C. H., and G. C. LaBrecque. 1959. Acceptability and toxicity of poisoned baits to houseflies resistant to organophosphorus insecticides. Jour. Econ. Ent. 52(2):345-46.
Service, M. W. 1964. Dieldrin resistance in *Anopheles funestus* Giles from an unsprayed area in Northern Nigeria. Jour. Trop. Med. and Hyg 67:190.
Service, M. W., and G. Davidson. 1964. A high incidence of dieldrin resistance in *Anopheles gambiae* Giles from an unsprayed area in Northern Nigeria Nature 203:209-10.
Smith, W. W., and W. C. Yearian. 1964. Studies on behavioristic insecticide resistance in houseflies. J. Kansas Ent. Soc. 37(1):63-77.
Tompkins, W. A. 1953. An apparent case of rotenone tolerance in a blue gill *Lepomis macrochirus*. Trans. Kentucky Acad. Sci. 14:43.
Ungureanu, E. M. 1964. Eighth summary on physiological resistance to chlorinated hydrocarbon insecticides in adult anopheline malaria vectors. W.H.O./Vector Control/71, 19 p.
Vinson, S. B., C. E. Boyd, and D. E. Ferguson. 1963. Aldrin toxicity and possible cross resistance in cricket frogs. Herpetologia 19(2):77-80.
Vinson, S. B., C. E. Boyd, and D. E. Ferguson. 1963b. Resistance to DDT in the mosquito fish, *Gambusia affinis*. Science 139:217-18.
World Health Organization. 1957. Seventh Report, Expert Committee on Insecticides. Wld. Hlth. Org. Tech. Rept. Ser. 125.
World Health Organization. 1963. Thirteenth Report, Expert Committee on Insecticides. Wld. Hlth. Org. Tech. Rept. Ser. 265.
World Health Organization. 1964. Malaria Eradication in 1963. W.H.O. Chronicle 18(6):199-215.
World Health Organization. 1965a. Animal lessons in human medicine. World Health. April, 1965. p. 24.
World Health Organization. 1965b. Malaria Eradication in 1964 W.H.O. Chronicle 19(9):339-53.
Yule, W. N. 1964. Materials and methods for a Canadian survey of insecticide resistance in agricultural pests Pesticide Progress 2(3):71-72.

BIOLOGICAL CONTROL STUDIES OF *MUSCA DOMESTICA* AND *FANNIA* SP. ON SOUTHERN CALIFORNIA POULTRY RANCHES

CLAYTON W. MCCOY
University of California, Riverside

It is common knowledge among workers associated with fly control programs that poultry ranches exhibit an ideal environment for the reproduction of many species of "domestic" or "filth" flies.

Due to their tremendous reproductive potential and their annoying behavior, *Musca domestica* (L.) and *Fannia* sp. have been the chief target for control on ranches throughout southern California. However, a satisfactory control has been difficult to maintain for numerous reasons.

Being aware of these difficulties the Department of Biological Control, University of California, Riverside, has conducted a study of the natural enemies of the housefly and its allies with the development of a biological control program as the primary objective.

Few attempts at biological control, which differs from natural regulation through man's intervention, have been conducted. Simmonds (1929) reported the importation of the hymenopterous parasite, *Spalangia cameroni* (Roh.) from Hawaii to Fiji to combat *Musca domestica*. Similar attempts to control houseflies were expanded to Guam in 1931 with *Spalangia* sp. as the natural enemy (Jenkins 1961). In neither case was the degree of success exhibited by the parasitic hymenopteran reported.

The use of predators as biological control agents has received extensive quantitative evaluation. Simmonds (1940), Phillips (1934) and Pimental (1954) have reported fly suppression due to egg predation by ants. The predaceous habits of a certain dung infesting machrochelid mite, *Machrochelus muscaedomestica,* are quite effective on the *Musca domestica* eggs. (Axtell 1961).

Other closely related Diptera, *Muscina* sp. and *Ophyra leucostoma,* have been shown to be effective in the destruction of housefly larvae (Anderson 1964).

Also, the use of the pathogen *Bacillus thurengiensis* Berliner as a poultry feed additive has been studied for use in the control of houseflies (Hall 1959).

Our initial biological control attempts against houseflies on poultry ranches in southern California began in April of 1963. Four species of parasitic hymenoptera, *Spalangia endius* (Walker), *Spalangia cameroni* (Roh.), *Spalangia nigroaenea* (Curtis) and *Muscidifurax raptor* (Girault) introduced from the West Indies and midwestern United States were mass-reared and liberated throughout the summer on poultry ranches in Orange County and in the Riverside area. In order to conduct a more specific study of the habits of *Muscidifurax raptor,* it alone was liberated in the Riverside area and it is this species which we will be discussing in this paper.

The poultry ranch selected for study used a suspended cage laying operation. The operation consisted of 13 cages with intervening aisles 80 to 120 feet long. Cones of manure accumulated on the ground beneath the cages for a period of five months before cleaning operations were carried out. Insecticidal control was discontinued for the duration of the study.

A parasite-host survey of the ranch was conducted biweekly for six months before *Muscidifurax raptor* was first released. During this time *Spalangia endius* was the only parasite found.

Among the host population the *Fannia* sp. population density began its incline in mid-April and reached a peak in late June. On the other hand, *Musca domestica* populations remained considerably higher throughout the year with a peak in mid-August.

The first recovery of *Muscidifurax raptor* occurred on June 14, approximately three weeks after parasite releases began. However, recovery was not repeated until the last week of July. From the 15 recoveries, the percentage parasitization of the host pupae was on the average never greater than 25 percent.

To better evaluate the efficiency of the parasite in the field, cage situations were established in mid-August when the *Musca domestica* population density was at its peak.

Four cages, 24 x 18″, enclosed with 32 mesh plastic screen sides and a solid plastic top, were placed over cones of manure and sealed at the base. Approximately 1,000 female parasites were placed in each cage for inundation purposes. An adjacent cage without the addition of parasites served as a check. Similar temperatures prevailed inside and outside the cages throughout the experiment. After 12 days the cages were removed and the cone was sectioned into layers for sampling. The entire upper 6 inches of the cone consisting of dry hardened manure constituted the first layer. The second layer, beginning at the soil level, comprised a mixture of dry manure and soil two inches deep. Below the soil level where a moist mixture of soil and organic matter occurred collections were made at 2-inch levels until pupae were no longer found.

The host pupae were then separated from the manure by flotation and held in the laboratory at 80°F. for parasite emergence. The results of the study represented by the slide are as follows:

The host pupae, 98% consisting of *Musca domestica* were most abundant from 0 to 4 inches below the soil surface. Pupation was undoubtedly stimulated by the presence of the moisture line in this region.

The mean percentage parasitization was significantly greater in the upper 6 inches of the cone where the concentration of host pupae was least. The dry, porous condition of the manure in this upper layer probably facilitated host-finding, whereas, at the other levels where hosts were abundant, their parasitization was uniformly less. The compactness of the soil-manure media in these regions presumably hindered host-finding and thereby caused this marked reduction in parasitization.

The inability of the parasite to find host pupae at the levels of their greatest concentration may partly

	Sample Level	Mean No. Pupae Per Sample	Mean Percentage Parasitization[b]
Above Soil Surface	2-8″	12.5	41.45
	0-2″	48.2	18.70
Below Soil Surface	0-2″	117.6	21.30
	2-4″	182.5	19.82
	Below 4″	14.0	18.99

Figure 1. Distribution and Incidence of Parasitization of Housefly Pupae Within and Beneath Coned Poultry Manure[a].

[a]Figures represent means of 4 replications.
[b]Means bordered by line show no significant difference at the 1% level of probability by Duncan's multiple range test.

explain the increased adult population densities throughout the summer as well as the low percentage parasitization obtained in field-collected samples.

In comparing the parasitization in the inundated cages with that in the check, in most cases the percentage control in the check exceeded that of the parasite containing cages. One can only speculate as to an explanation for this occurrence.

Due to the increased parasite density within the inundated cages, overcrowding or superparasitism might have influenced the results. However, laboratory conditions with a similar parasite-host density displayed normal parasitism.

As shown by these data parasitization at the different cone levels was uniformly low. This degree of parasitization might have been the maximum under the given conditions. Therefore, if the accessibility of the host to the parasite was at a maximum, inundation with 1 or 10,000 parasites would not change the percentage of the hosts parasitized.

It should be mentioned that the Orange County study produced different results. In this area *Fannia* sp. was the primary host throughout the summer. The percent parasitization due to the parasite activity of *Spalangia* and *Muscidifurax* exceeded 70% in areas within 100 feet of the release sites. The pupation sites of *Fannia* sp. being different from that of *Musca domestica* may have some bearing on the success in this area.

A PRELIMINARY STUDY OF INTEGRATED FLY CONTROL ON NORTHERN CALIFORNIA POULTRY RANCHES

JOHN R. ANDERSON
University of California, Berkeley

Over the past several years in northern California studies conducted on the ecology, behavior and control of flies have revealed that the poultry ranch constitutes a complex ecosystem. Results of some elements of the above research were reported to this association at last year's annual meeting, at which time I indicated the scope of the invertebrate and vertebrate fauna associated with chicken droppings (Anderson, 1964). In addition to many different fly species one finds such natural enemies of flies as fungus diseases, parasitic hymenopterous wasps, and the following predators: the European earwig; the venomous, snake-like larvae of the black garbage fly which feed on other fly larvae; predacious mites which feed on eggs and early-instar fly larvae; vespid hunting wasps; beetles, spiders, and birds. Most of these beneficial animals spend as much or more time on the droppings than the flies, but unlike fly larvae most of the natural enemies are associated with the exposed surface of droppings. The natural enemies are, therefore, more at risk from insecticides, flames or other fly control measures applied to the droppings than are the developing fly maggots.

Another important finding in previous studies was that during the daylight hours populations of various flies and certain of their natural enemies were widely dispersed about the ranch premises, but that at night, the two major nuisance species (the housefly and the little housefly) aggregated at different resting sites than their winged natural enemies—specifically, adults of the black garbage fly and various parasitic wasp species (Anderson, 1964; Anderson and Poorbaugh, 1964). About 90% or more of the total ranch population of these nuisance flies rested and remained in the ceiling area of poultry houses from dusk until about midmorning. The above natural enemies, however, aggregated primarily at outdoor sites during the night—largely in nearby trees.

Aware of the natural enemy fauna in droppings and the differential night resting sites of the winged forms, one objective in 1964 was to determine if selective application of insecticides to only the area in which flies predominated at night would kill most flies on a ranch without reducing populations of certain of their natural enemies.

Methods—Six Sonoma County ranches were included in the study, with each being sampled in the same numerical order each week. All were of the suspended cage-type laying operation. One ranch (A) served as a check to which no insecticides were applied during the entire season. On 3 ranches (C, D and E) insecticide (1% dimethoate or ronnel or 2.5% malathion) was applied to only the droppings, outer walls and surrounding vegetation, and on 2 ranches (B and F) insecticide (1% ronnel or snip [dimetilan] fly bands was applied to only the ceiling area of poultry houses. The snip fly bands were installed at Ranch F on May 8. Ranch B was sprayed on April 22, June 30, July 20, and August 17, and Ranch C was sprayed by the rancher on March 29 and by research personnel on June 23, July 10, August 6, August 27 and October 12. Ranches A, B and C were all situated at the edge of a coastal, summer fog zone (near Sebastopol) with B and C being about one mile apart and 3 and 4 miles from Ranch A. Ranches E and F were located in a sunnier, warmer climatic area (near Windsor) about 10 miles north of the other 3 ranches. As in previous years we measured population fluctuations of flies and their winged natural enemies by sticky fly tape samples, Scudder grill counts and suction machine samples. The sticky tapes were hung vertically from overhead aisle beams within poultry houses from 4:00 p.m. to 10:00 a.m. the following day. Suction samples were taken over the droppings, down the aisles, in grasses adjacent to houses and from the branches of nearby trees. In addition to *Musca domestica* L. and *Fannia canicularis* (L.), populations of the following natural enemies were sampled: 3 species each of parasitic hymenopterous wasps and predacious mites and the black garbage fly, *Ophyra leucostoma* Wied.

To determine the effect on the fauna living in the droppings when insecticides were applied to the droppings, one-pint manure samples were obtained each week, from each of 4 locations on the ranches. Mites were separated from half of each sample with a Tullgren-type funnel and fly larvae were separated from the other half by salt flotation. Fly larvae and all specimens in a 50 ml. aliquot of the mite sample were subsequently identified.

Results—Results of this preliminary investigation on the possibilities of integrating chemical with biological control of nuisance flies concern primarily comparisons of the densities of *M. domestica* and *F. canicularis* and certain natural enemies when no insecticide was used (Ranch A) versus those densities occurring when ronnel was applied to the droppings, outer walls of houses and the surrounding vegetation (Ranch C) or when it was selectively applied to only the ceiling area (Ranch B) and where snip (dimetilan) fly bands were suspended overhead near ceilings (Ranch F). Sticky tape samples only were obtained for Ranch E (therefore no population samples obtained except for flies) and Ranch D withdrew from the study in August.

Large populations of all representative natural enemies and all flies except houseflies remained high through the season on the check ranch. In weekly samples from mid-July through September for example, the number of predacious mites per pint of manure fluctuated between 100 and 1,000 and the number of parasitic wasps averaged 13 per 100 linear foot suction sample over droppings. The number of *F. canicularis* per sticky tape fluctuated from 50 to 300 between late April and mid-July, but dropped to 25 or less after July 15. This seasonal decline in the little house fly population is typical for northern California and on this ranch paralleled the increase in numbers of natural enemies. Predacious mites increased from zero prior to mid-June to about 20 per pint until mid-July, and the number of parasitic wasps caught in suction samples over droppings during July and August was almost double the number caught during May and June. Also associated with the large numbers of parasites and predators on the check ranch was the fact that the catch of *M. domestica* did not exceed 10 per sticky tape until mid-October (when populations of natural enemies had declined). No mites were recovered from October samples and the number of parasitic wasps caught then was about the same as for May and June. Manure was not removed from under cages on the check ranch during the study period (April 15 through October 21, 1964) and none had been removed for more than a year prior to April 1965.

When insecticide was applied to droppings, outer walls and adjacent grass (Ranch C) a marked reduction (82% to 92%) in flies occurred following each spraying, but usually within 2 weeks the fly population had increased to a point where another application of insecticide was necessary to again reduce their numbers. Throughout the summer and fall on this ranch acceptable fly control (an average of less than 30 *M. domestica* or *F. canicularis* per sticky tape) was achieved for only brief periods (2 to 3 weeks) following each spraying. The measured housefly population was less than 30 per tape on only 5 of the 17 weeks sampled from July 1 through October 21 and it exceeded more than 100 per tape on 5 weeks and between 50 and 100 per tape on 7 weeks.

On Ranch B (ronnel applied to only the ceiling area) the *F. canicularis* population was reduced 95% following an April 22 treatment and did not exceed 10 flies per tape until the 6th week post-treatment. After a second spraying on June 30 the little housefly population remained below 5 per tape for the remainder of the season. From July 1 through October 21 the housefly population never exceeded more than 50 per tape and exceeded more than 30 per tape on only 4 of the 17 weeks sampled during this period. On Ranch F (receiving 160 snip fly bands at the rate of one band per 75 sq. ft. of ceiling area) the little housefly population was reduced 92% by the second week (May 20) after installation and reached a high of 21 to 25 flies per tape on only 3 of the 9 weeks sampled up to July 15. Except for 2 catches (one of 8 and one of 6 flies per tape) between July 15 and October 21, the little house fly population remained below 5 per tape. After the house fly population first exceeded 10 per tape on August 5, it dropped below 30 per tape on only 2 of the 12 weeks sampled through October 21. It reached from 50 to 60 on 3 weeks and between 30 to 47 on 7 weeks.

The application of insecticide to droppings had a more deleterious effect on the natural enemies than it did on the flies. After each spraying no predacious mites were detected in samples for about 2 weeks, after which they slowly increased in number. Following 2 successive applications to droppings on Ranch C (June 23 and July 10) the mite populations required 8 weeks to regain their pre-treatment densities. Snip fly bands had no effect on mite populations, for on Ranch F the mites usually averaged between 50 to 100 per pint of manure during the study. Although mite populations were lowest on Ranch B (ceiling areas sprayed with ronnel) they were not reduced following treatment as they were when this insecticide was applied to droppings. The different breed of chickens on Ranch B (Rhode Island Reds versus White Leghorns on other ranches) produced a wetter and different textured dropping which was more difficult to process for mites and appeared less favorable for mites.

Black garbage flies (whose larvae are predacious on various other fly maggots) were 3 to 5 times more abundant on the ranch sprayed only overhead with ronnel or receiving snip fly bands than they were on the ranch where droppings were sprayed with ronnel. The number of parasitic hymenopterous wasps on the ranch treated with snip fly bands compared favorably with the population on the check ranch receiving no insecticide, but on all other ranches parasitic wasps were not collected frequently enough or in large enough numbers in either pre- or post-treatment samples for any conclusions to be drawn.

The combination of an abundant natural enemy population (mites, parasitic wasps and black garbage flies) coupled with snip fly bands on Ranch F did not provide as good control of the housefly population after manure removal as one would like. This appeared related to the fact that there was a large area of potential, untreated resting surface (numerous overhead cage support wires, electrical wiring and beams) competing with the insecticide-treated bands. By selectively spraying ronnel to the ceiling area only on Ranch B a better reduction of flies was achieved than when Ranch C was more thoroughly covered by application of the same insecticide to droppings, outer walls and surrounding vegetation. Further, the better per cent reduction of flies through selective application of insecticide was achieved with about half the volume of insecticide and without reducing populations of certain natural enemies of flies.

An interesting association noted on all ranches except for the last week samples were taken on the check ranch (Oct. 21), was that regardless of temperature the measured housefly populations did not exceed 10 per tape until after manure removal from the poultry houses was initiated. Although house flies were first detected much earlier in the warmer area (April 15 on Ranch E and May 12 on F as compared to July 1 on A, July 8 on B and June 17 at C) and remained constantly present thereafter until the study terminated on October 21, each initial sudden increase in numbers of *M. domestica* on each ranch followed the removal of manure. House flies first increased to more than 10 per tape at Ranch E in the warm area on June 3 (2 weeks after manure removal had begun). For the 3 ranches located near one another in the cooler, fog area, the *M. domestica* population first exceeded 10 per tape at Ranch C on June 24, and at Ranch B on July 15. They did not exceed this density on Ranch A (no manure removal) until October 14. Although Ranch F was located in a warmer climatic area than Ranches B and C the housefly population here did not exceed 10 per tape until August 5 (after manure removal).

The fact that on all ranch house flies first increased to more than 10 per tape within 2 weeks after manure removal operations had begun suggested that the increased numbers of flies were being attracted to the ranches during the period of manure removal rather than being produced on the ranches and emerging in greater numbers by coincidence at the time each rancher decided to remove manure. Also associated with the small increase in flies during or shortly after manure removal was the fact that populations of house flies underwent their first sharp rise to pestiferous levels of more than 30 and often more than 50 or 100 per tape at 3 to 4 weeks post-manure removal. Depending on the method used, complete manure removal usually required from about one to three weeks. On all ranches manure removed from the houses was stockpiled on ranch premises usually about 50 feet from the nearest poultry house. Whenever older manure was removed from dropping pits below cages no predacious mites were found in samples taken from the fresh droppings until about 3 weeks post-removal. New accumulations of fresh, wet droppings were considerably more conducive to housefly propagation than to repopulation by mites. Mite populations required a longer time to recover (2 to 3 weeks) following manure removal than they did following applications of insecticide to droppings.

Although the results of an integrated approach to fly control appear promising, many unknowns remain. Two prominent unknowns being the effect manure produced by different breeds or ages of chickens has on the predacious mite and other predator fauna, and the effect manure removal has on the fauna when it is removed at different times of the year.

I wish to thank Messrs. B. C. Nelson and J. H. Peck, graduate research assistants, for their help in taking weekly samples and identifying specimens, and Mrs. B. Billeb, research technician, for taking and processing manure samples.

References Cited

Anderson, J. R. 1964. The behavior 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. 1964. Observations on the ethology and ecology of various Diptera associated with northern California poultry ranches. **J. Med. Ent.** 1(2): 131-47.

MOSQUITO CONTROL INVESTIGATIONS

Mir S. Mulla
University of California, Riverside

The various phases of mosquito control technology investigated during the past year are discussed below.

Mosquito Larvicides—About 25 new materials belonging to the organochlorine, organic phosphate and carbamate groups of insecticides were evaluated. Among these, 5 materials were found to have exceptionally high level of biological activity against a susceptible strain of *Culex p. quinquefasciatus*. Their activity surpassed or approached the activity of parathion against the same strain. These materials were: SD-9020, Bayer 64995, GS-13005, SD-8803 and SD-9321, listed in the order of decreasing biological activity.

Ronnel, Nia-10242 (a carbamate), SD-8211 and GC-9160 (a chlorinated hydrocarbon) showed activity similar to that of DDT. The remaining materials listed in decreasing order of activity are: N-3794, N-4328, RP-1197, SD-8447, SD-8530, SD-9129, UC-21149, GC-9879, UC-19786, UC 21427, N-4330 and UC-20047. The lower level of activity of these compounds against an inbred susceptible strain of *C. p. quinquefasciatus* provides no indication of the effectiveness of these against parathion, DDT, dieldrin and other insecticide resistant strains or species. Compounds having negative correlation to resistance are difficult to detect unless the evaluation and screening program are materially increased. It is interesting to note that the effectiveness of GC-9160 and UC-21149 against DDT and dieldrin resistant *C. tarsalis* in the field was far greater than the level of its effectiveness which could be predicted on the basis of their activity against the laboratory population of *C. p. quinquefasciatus*. It therefore becomes desirable that most compounds should be evaluated in the field so that those having negative correlation with resistance can be singled out. At the present time, there is no way of telling compounds of this type either by chemical or physical means.

Petroleum Oils—Petroleum oils have a special place in our mosquito control programs in California. The mode of action and the factors determining the efficiency of these oils in mosquito control are not clearly understood. In order to utilize these products more effectively and economically, a program of research to study the basic relationships was established. Information on the mode of action of petroleum oils, whether they affect enzyme systems or kill by suffocation, or produce mechanical or physiological injuries in the tracheal system, would prove useful. The old concepts of oils acting through the blockage of the tracheal system need drastic revision. Critical evaluation of capillarity, surface tension, film phenomena, spreading coefficients, broken films, continuous films, surface active agents and speed of action of a particular system will be advanced.

In the first phase of this program, it became necessary to ascertain the biological activity of various fractions of a variety of petroleum oils. Three cuts of oil with and without surface active agents were evaluated against 4th instar larvae of *C. p. quinquefasciatus*. The fractions of each oil ranged from low boiling to high boiling viscous fractions.

The performance of WTL type oil at 100 p.p.m. with 2% Atlox 1256 was low for fraction 1 and 2 which are the low boiling products. Fraction 3 produced 98% kill while fractions 4-9 inclusive produced 100% mortality of the larvae. Fraction 10 was too viscous to be tested. In the FLC series, fractions 1-4 did not produce over 92% mortality. Fractions 5-10, however, caused mortalities ranging from 96-100%. Fractions of oil cut 142 produced interesting results. Fraction 3 yielded 99%, fraction 4 and 5 each produced 100% mortality. The activity of other fractions at either end of the range was lower. Fraction 8 and 9 produced only 32% and 34% mortality respectively.

These three oils when used without surfactant, produced different results. Without surfactants, the low boiling fractions of WTL caused slightly higher mortality than with the surfactant. The two highest boiling fractions tested without surfactant were less active. The low boiling FLC fractions were slightly better without than with the surfactant. Fractions of 142 at both ends of the distillation range showed considerably higher level of activity without than with a surfactant.

Speed of action of oils is another important problem; some oils will kill quickly while others will kill slowly. With some oils the larvae can live for days before they will die, and routine 24-hour post-treatment inspection will rule these treatments as failures. Some larvicidal oils have been observed to kill pupae but not larvae, and it is not easy to kill young instar larvae with certain oils. The capillary characteristics of siphon tubes and tracheae as well as surface phenomena enter into the picture.

Mating Age—The aim of these studies was to determine the age of mosquitoes at which they commence to mate. This information was deemed necessary for obtaining virgin males and females for chemosterilant studies.

Males and females of *C. p. quinquefasciatus* emerging from pupae in emergence cages were isolated from each other at intervals after emergence. In this manner the period during which mating commenced was determined.

Females isolated from males 24 hours after emergence laid fewer eggs than females maintained together with males, and none of the eggs hatched, indicating absence of mating during the first 24 hours after emergence. Females isolated 42 hours after emergence also produced fewer eggs, none of which hatched out. Females isolated 48 hours after emergence also deposited fewer eggs, 9% of which hatched, indicating some mating during the period of 42-48 hours after emergence. Females isolated 72 hours after emergence laid quite a few eggs but not as many as the check treatment, and the per cent hatch of these eggs was 45% or ½ of the check treatment. Females isolated 96 hours after emergence laid just as many eggs as the check treatment and the per cent viability of the two treatments was essentially the same.

The effect of lack of mating on the number of eggs laid is rather pronounced. This effect on oviposition due to differential mortality of male mosquitoes on exposure to chemosterilants should be taken into account. Care should be taken to minimize male mortality due to feeding or contact with a sterilant.

Chemosterilants—Chemosterilants have been found to be effective against both the larvae and the adults. Larvae of *C. p. quinquefasciatus* were reared in chemosterilant solutions until they pupated. The pupae were removed to clean water and the emerging adults were mated in a combination of crosses. Sterile males coming from larvae exposed to the chemosterilant apholate (0.002%) were crossed with fertile females. These females deposited a large number of eggs, but none of the eggs hatched. A mating cross of fertile males and sterile females resulted in no egg deposition. Similarly, a cross between sterile males and sterile females produced no eggs. That female mosquitoes sterilized with chemosterilants lay very few or no eggs is in agreement with other studies.

Females isolated from males before mating took place laid very few eggs of which none hatched. This point is well illustrated in the previous section.

Metepa at 0.01% produced results similar to those by 0.002% of apholate, except that metepa did not induce complete sterility when the larvae were exposed to this concentration. It is very likely that metepa may have to be used at 0.02 or 0.03% for obtaining complete sterility.

Against adult mosquitoes the chemosterilant metepa offered as 0.1% sugar bait proved very effective. A cross between sterile males fed for a period of 8 hours on this bait and fertile females produced normal complement of eggs, the viability of which was about 67%. A similar cross, but where the males fed on the chemosterilant bait for 24 and 48 hours produced normal number of eggs but the viability was only 4% and 3%, respectively. The reverse cross (fertile males x sterile females) where the females were allowed to feed for 8 and 24 hours, produced reduced number of eggs; their viability being about 54% and 52%, respectively. Females fed for 48 hours and crossed with fertile males produced no eggs. It is apparent that the feeding period for an effective sterilization is longer for the females than for the males. The degree of induced sterility was quite high (4% viability) when both males and females fed for 8 hours were mated. Feeding periods of 24 hours and 48 hours for both sexes and mated then, produced markedly reduced number of eggs in the first feeding period and no eggs for the second feeding period.

Apholate as 0.01% sugar bait produced results similar to metepa. Complete sterility was obtained when the females were fed for 72 or 96 hours and mated with normal males.

Other chemosterilants evaluated were: OM-53139, OM-53264, OM-53362 and OM53356 were not too promising as water solutions against the larvae.

Similarly, U-7726, U-10071, U-15800 and HPT inhibitor did not show much promise against the larvae. U-14743, however, induced complete sterility when 4th or 2nd and 3rd stage larvae were exposed to 0.001%

of transmission are largely circumstantial and fragmentary.

The preceding brief summary indicates that a number of viral diseases and at least one bacterial agent are transmitted to man by mosquitoes or gnats or have such potential in California. The threat of epidemic events or the discovery of new diseases that are carried by these vectors must continue to be a matter of concern and active research.

I would like to turn now to a different public health or medical aspect that also is a program concern.

Direct Attack—The annoyance caused by direct attack of mosquitoes and gnats on man either through biting or the mere presence of large numbers is of more concern to the average citizen in most years than is the transmission of disease agents. The loudness, repetitiveness, and tone of the public's complaints clearly document that they consider such annoyances are important to their physical and mental health. However, an objective evaluation of the direct or indirect public health significance of this problem is most difficult to obtain.

One study was done in California in 1958 when there was a high population of *C. tarsalis* (Reeves and Renteln, 1959). Time will not permit a detailed review of the procedures and findings; however, a summary of some of the findings will illustrate the value of such studies (Tables 2 and 3). I submit that the health of this population was affected adversely and that the further refinement of research techniques to adequately measure this problem would be a valuable tool to further document the value, need for, and effectiveness of mosquito control programs.

Table 2—Summary of mosquito attack rates—Kern County residents, 1958.

	Persons interviewed	Persons bitten	Per cent bitten
Attacked entire summer	502	316	63
Urban residents	377	207	55
Rural residents	115	102	89
Attacked past 24 hours	486	134	28
Urban residents	376	78	21
Rural residents	110	56	51

Current Research Project on Arboviruses—I would like to turn to a brief summarization of the current research project on arboviruses of the School of Public Health. This is a cooperative project with the Technology Branch of the Communicable Disease Center, U.S.P.H.S.; the Bureau of Vector Control of the California State Department of Public Health; and the Kern Mosquito Abatement District. The eight objectives of this current program are:

1. To study the interrelationships of hosts, vectors, viruses, and environment that control the endemicity and epidemicity of WEE and SLE viruses.
2. To evaluate the effectiveness of an intensive *C. tarsalis* control program as a means of stopping virus transmission, as well as to prevent human and equine disease.
3. To develop more complete knowledge of the bionomics of the primary mosquito vector *C. tarsalis* as a basis for a better understanding of virus transmission cycles and for more effective control.
4. To evaluate alternative hypotheses concerning overwintering reservoirs of arboviruses and the relationship of such knowledge to alternative approaches to control.
5. To establish combined laboratory and field studies on the pathogenesis and ecology, and public health and veterinary importance of 12 arboviruses known to occur in California.
6. To study the blood-feeding habits of mosquitoes and gnats as an approach to the clarification of vector-host interrelations.
7. To evaluate the role of mosquitoes and gnats other than *C. tarsalis* as vectors of arboviruses in California.
8. To develop and distribute "A Catalogue of the Arboviruses of the World" and abstracts of associated publications.

The above project has evolved and been operative since 1943 with field investigations centered in Kern County and base laboratory facilities in Berkeley. A large budget has been required for investigation of this diversity of problems and particularly for support of the extensive laboratory staff and facilities for virologic and immunologic studies that service the field investigations. The present annual budget exceeds $200,000 per year. Project development was accomplished by obtaining research grants and collaboration from other agencies for cooperative research under University direction. The project has been somewhat unique; first as to the extent and effectiveness of the collaboration; and second, in the limited financial support it has received from the State of California. The present degree of support from state funds is the maximum received: this is $36,500 from the Bureau of Vector Control through assignment of personnel and vehicles, and the salary of the project director and physical facilities from the University. Rent-free facilities for the field station have been provided by the Kern County Board of Supervisors and the Kern Mosquito Abatement District.

The stability and continuity of this research project and the staff have been threatened annually by the need for renewal of research grants, and by the uncertainties of state legislative or federal congressional support to the collaborating agencies.

Table 3—Distribution of estimated number of bites in the past 24 hours, Kern County residents, 1958.

Persons bitten	Estimated number of bites 1-4	5-9	10-19	20-29	30+	Not determined
137	66	33	14	5	4	15

Future Proposals—It has been and is unrealistic to request *full* budgetary support for this project from state sources. The scope and objectives of the studies have interests and support that extend beyond state boundaries. However, a request is being made currently for state support to the University to provide a nucleus staff of competent professional workers to assure continuity, expansion, and acceleration of investigations over a period of years. The proposed initial staff will include a professional or technical worker from each of the following fields: medical epidemiology, medical entomology, vertebrate ecology, virology, and immunology. This staff would participate in and strengthen the research activities outlined earlier, and would allow an acceleration and broadening of the program with reference to:

1. The significance of new arboviruses as causes of disease in man, domesticated animals, and wildlife in California.
2. Evaluations of the public health significance of direct attacks of mosquitoes and other blood-sucking Diptera on man and domesticated animals.
3. Expansion of the studies on host-feeding patterns of blood-sucking arthropods.
4. Development of collaborative programs with other University and public health agencies for the epidemiologic study of follicular conjunctivitis.
5. Provision of a more effective research unit for consultive or collaborative work with other units of the University and public agencies that share mutual interests in the relationships of mosquitoes and gnats to disease problems.
6. Investigation of epidemics in any part of the state.

Summary and Conclusions—The preceding discourse has outlined the history, progress, extent, and future plans for studies by one section of the University on diseases associated with mosquitoes and gnats in California. This field has many ramifications and technically is difficult. The resources of the state are limited; however, the plans for development of a more extensive and balanced program of research in the University should accelerate progress in the development of more effective control programs.

References

Reeves, W. C. 1964. Newer developments in arthropod-borne viruses in California. Proc. and Papers California Mosquito Control Assoc. 32:78-81.

Lennette, E. H., R. L. Magoffin, W. A. Longshore, and A. C. Hollister. 1961. An etiologic study of seasonal aseptic meningitis and encephalitis in the Central Valley of California. Am. J. Trop. Med. Hyg. 10:885-96.

Lennette, E. H., R. L. Magoffin, and E. G. Knouf. 1962. Viral central nervous system disease. An etiologic study conducted at the Los Angeles County General Hospital. J.A.M.A. 179:687-95.

Reeves, W. C., and H. A. Renteln. 1959. Determination of mosquito attack rates by interview of Kern County, California residents. Mosquito News 19:274-79.

CMCA SUMMARY—BIOLOGICAL CONTROL

Ernest C. Bay
University of California, Riverside

The biological control of medically important insects has only recently begun to receive serious attention, but already worthwhile developments have come of it and truly exciting prospects lie ahead. As you know, I am particularly, though cautiously, excited about my own work with the annual fishes in this respect. The World Health Organization currently shares my enthusiasm for these fish and they are supporting the establishment of experimental colonies in such removed locations as Bulgaria, India, and the Solomon Islands.

Dr. Lauren D. Anderson has this afternoon brought you up to date on some of our aquatic midge research. As most of you know, we earlier discovered that carp give excellent biological control of Chironomidae in certain situations, but they are apparently of little value in others. Thus, like all controls, be they chemical, cultural, or biological, carp can only be thought of as special tools for special jobs.

An even more specialized tool is the insect pathogen. The *Gurlya* species of Microsporidia which was discovered by one of our graduate students, Mr. Kent Hunter, to attack the midge *Chironomus californicus* has so far been found to be completely host specific. Likewise, many of the *Coelomomyces* fungi and viruses found to attack mosquito larvae seem to be ultra host specific.

In addition to their attribute of host specificity, pathogens are additionally attractive in that they are suitable to mass production and dissemination techniques like those used for chemicals. Meanwhile they lack the stigma of having toxic residues.

Mr. McCoy's work with the parasite *Muscidifurax raptor* would seem to discourage prospects for its use in *Musca domestica* control on Riverside poultry ranches, but as he states, according to Dr. Legner's work, it may be a very useful agent against *Fannia* species inhabiting poultry manure in Orange County. Biological control advances are also being made in the difficult battle against the *Hippelates* eye gnat. Several hymenopterous parasites of the eye gnats have been first discovered in California and the West Indies within the past 3 years. Although none of these so far promises to be very successful, Dr. Legner, of our Department, is currently seeking others in latitudes south of the border similar to our own where *Hippelates* also occur but are less of a problem. The techniques developed in discovering the earlier parasites are invaluable to Dr. Legner's present effort. Meanwhile these same techniques have recently enabled Mr. Lenord Moore to discover a very promising beetle predator of *Hippelates* pupae in the Coachella Valley. Mr. Moore will speak on his find later in the conference.

In closing, I will only state that those who expect to find an ultimately satisfactory and permanent control by any one means, chemical, biological, or whatever, are doomed to face disillusionment.

As with other means, there have been excellent solutions to many insect problems found in biological control in the past and we expect that there will be many more in the future. However, it must always be remembered that whatever the tool it must be fitted only to its proper job.

THIRD SESSION

TUESDAY, JANUARY 26, 9:00 A.M.

OPERATIONAL EQUIPMENT AND PROCEDURES

A. H. THOMPSON, JR., *Moderator*

GRANULE APPLICATIONS

DONALD A. MERRITT
Consolidated Mosquito Abatement District

We have completed our fifth year working with hard core granules as an easy, clean way to treat a multitude of larvae sources. In fact, the use of impregnated materials goes back about ten years when we were impregnating porous material with insecticide, and even oil, and doing excellent *Culex* control in confined places. This was carried on for several years until the start of the 1961 season when the District initiated a full scale program on the use of granules.

The type of equipment that we have had experience with or used is as follows:

Hand Crank Seeder—Without going into detail on the many hours spent in constructing, remodeling and repairing the hand crank seeder it does have merit and will be used and explored further.

Power Seeders (broadcasters)—Power broadcasters mounted on vehicles, some using auxiliary motors and some using power take-offs, have been proven in the field. The Anderson Broadcaster is the one I am familiar with and it probably is the only make being used in our area.

Airplane—None have been used in Consolidated but I know from the reports of other districts near us that it is a very practical method of applying hard core granules.

Horn Seeder—The original Cyclone Horn Seeder has been modified, remodified and then modified again. First we eliminated the cloth or canvas bag trying to get a material that would not absorb any toxicant. We then zippered the opening to protect the operator from spillage and fumes. We changed the shape two or three times to get better arm action or comfort for the operator or better flow to the gauged section. We then tried a knapsack type bag with a flex hose to the gauged section. We had two in operation through 1963 and 1964 and they are working well and suit the operator well and we will promote more this coming year.

At the present we are using a zippered bag made out of a rubberized material with an adjustable strap. The original cyclone gauge section is being used and the shape is similar to the original bag except that the outlet neck is longer.

Granule Shooter—Faced with the task of using granules to larvicide miles of weed-grown drain ditches, cattail-filled ponds and other large mosquito sources where liquid sprays had been used before, we started searching for something better and faster than the Horn Hand Seeder.

As all of our Jeeps are equipped with an air supply we experimented and designed a granule shooter that will shoot granules 35 to 40 feet.

At the same time we were experimenting with home-made models, I was looking over the commercial models that would perhaps fit our need.

We have in use at the present time the home-made model and the commercial model (Sandy Jet Blast Gun Model C9 with Air Jet 5/64″ and Sand Nozzle 13/64″) that was designed for small sandblasting jobs. After three years experience I prefer the commercial type to the home-made type mostly because of less stoppage and a more uniform application.

As I described the type of equipment it suggested the methods of application and at Consolidated we use only two methods to apply granules for larvae control. The method most commonly used is the horn seeder and the rate of application aimed for is 5 lbs. per acre of 1% material.

The other method used is the granule shooter which is a welcome aid for treatment of long drain ditches, tule ponds and gutters. The rate of application aimed for is 5 to 7 lbs. per acre. Table 1 shows the amount of granules being used in three locations.

Table 1. Granule application by three mosquito abatement districts.

Madera (Sand core 2% Parathion granules at 5 lbs./acre)		
Machine or broadcaster	69,000 lbs.	
Plane	27,175 lbs.	
Hand	97,855 lbs.	
	Total	194,030 lbs.
Fresno (San core 2% sand core granules at 5 lbs./acre)		
Machine or broadcaster	62,000 lbs.	
(1% Baytex)		
Machine or broadcaster	47,000 lbs.	
	Total	109,000 lbs.
Consolidated (Sand core 1% Baytex at 5 lbs./acre)		
Granule shooter	4,718 lbs.	
Hand	65,189 lbs.	
	Total	69,907

SAFEGUARDS USED IN HANDLING, APPLYING AND TRANSPORTING INSECTICIDES

CHET OWENS
Fresno Westside Mosquito Abatement District

The personnel of the Fresno Westside Mosquito Abatement District is proud of their record of safety in handling, applying and transporting insecticides.

The bulk of our mosquito control is accomplished by the use of chemicals. We apply these chemicals by airplane, ground equipment and hand equipment.

When we fabricated our spray equipment we had safety in mind to minimize the danger of handling, transporting and applying hazardous insecticides.

Before the operators go to the field to spray mosquitoes we have a training session on safety in the handling, transporting and applying of insecticides. We also make sure the operators have all the necessary material and equipment deemed necessary for safety, such as rubber gloves, soap, gallon canteen of water and a locked box for carrying the concentrate.

We use parathion almost entirely for controlling mosquitoes. The parathion concentrate is bottled into quart polyethylene bottles in tank charges to minimize the possibility of spillage. The quart bottles are carried in a box under lock on the jeep for filling in the field. Our operators empty their tanks to the point that a full bottle of concentrate is required for recharging. We do not allow them to use part of the insecticide from a quart bottle. We have a list of safety regulations which our operators must observe when filling the jeep tanks.

One person is assigned the job of filling the quart concentrate bottles and no one is allowed in the filling area except authorized personnel.

When we made up our transporting and loading equipment for our aircraft we made sure that we introduced as many safety factors as we could. One of the most important of these is minimizing handling of the insecticides.

ESTABLISHED SAFETY PROGRAMS FOR MOSQUITO ABATEMENT DISTRICTS

JAMES MALLARS
San Joaquin Mosquito Abatement District

An employee is in the shop overhauling the brakes on a jeep. Somehow, the jeep falls off the jack and the man receives a severely injured leg. An operator contaminates himself with parathion and awakens in a hospital bed. An employee is driving on a rural road closely following a farmer on a hay bailer. Suddenly the farmer turns and the jeep crashes into the bailer, resulting in severe whiplash injury to both individuals.

Later, a discussion is in progress at the office, "How is the employee convinced to practice proper safety procedures? What rules of safe-driving habits are lacking? How should equipment be designed and used to improve safety? Why is the general safety record in our district poor, or conversely, why do we have a good safety record?"

Perhaps the answers to exemplary questions is not a matter of thinking on the surface, so to speak. Perhaps they lie with hidden cause and effect. Predicated on the basis of concealed values, suppose we consider the following impressions and then examine several precepts of safety.

Not all the casualties in industry can be blamed directly on the failure of equipment being used. Rather it is often a combination of failures on the part of the equipment, materials, methods, and individuals using equipment that results in accidents. Safety then is in part a human relations problem.

It is not to be inferred that District operations can be made safe only through people. With all sorts of safety devices and precautions, accidents still occur. No single method is the absolute way of achieving safety. Working directly with the individual, however, is a rewarding approach to the whole problem.

We are not all of the same cast or mold. To work successfully with people, one must develop insight to try to understand them. What forces in people can be utilized to make a safety program effective? In seeking an answer we are concerned with an individual as he is.

Maintaining an employee's interest in safety calls, on occasion, for ingenuity and the ability to produce something with a new look.

All employees of the organization must support its safety program; otherwise, it is a hard task to capture an employee's interest. Employees may react favorably or unfavorably to the safety program. A person's approach and his ability to leave a favorable impression are vitally important.

On a certain morning an operator approaches you as his supervisor, stating he has a bad tire. Both of you are in a hurry. "Well, change the tire tonight," you remark. During the day the tire blows out; control of the vehicle is lost and the man is injured. You, as a supervisor, can be sued for as much as $7,500. This is an explosive thought, isn't it? Perhaps in your mind this illustration is easily discounted as unlikely. Nevertheless, the law is there and the incident could have been avoided through proper communication. Communication then is one precept of safety. Conversely, the operator should receive adequate training to communicate sufficiently with his supervisor.

You are in an airplane cockpit. Sitting beside you is a trainee. He is learning how to fly and is watching you intently. He observes the instrument panel, watches how the controls are maneuvered, and when the foot pedals are depressed.

After continuous observation and repetition, he is given the controls. Eventually, he is allowed to solo. Another precept of safety has been employed—that of creating confidence in the employee. Without confidence too many accidents occur.

It is a foggy morning in January. Two men have prepared a vehicle with the necessary equipment for the day's task of treating treeholes in the city. They are about to leave the yard and suddenly a supervisor stops them because he observes one feature. A ladder for climbing has been placed on the vehicle in a hazardous fashion. It is not lashed down; nor has a red flag been attached. After correcting the hazard, he glances around quickly and notices a dirty rear window on the vehicle, a frayed windshield-wiper, oil on the bed of the truck creating a slippery condition, and the gas cap still resting on the gasoline pumps. Furthermore, the long wand for treehole spraying has not been insulated against electric wires.

In this experience, the supervisor has exhibited a third precept of safety—that of awareness. Perhaps *awareness* is the prime requisite of safety. It is the ability to observe, *out-of-habit* conditions or happenings which may or may not be immediately obvious.

Awareness is the habit of daily living—it is noticing the new sugar bowl your wife has placed on the table, whether your car has a flat tire when you prepare to start it in the morning, and remembering to close the airvent petcock on a full drum of parathion because the newscast at breakfast said it would be hot today.

Mosquito abatement districts have instituted safety programs covering many obvious safety factors which would only be repetitious if stated here. Several additional aspects of safety which might be incorporated into district programs include the utilization of other agencies and the physical examination.

Inviting the Highway Patrol to the district can be highly rewarding to district programs. How many of us remember the three main causes of accidents during 1964 as disclosed to us through this agency—improper signaling on highways, thousands of new out-of-state drivers unfamiliar with California conditions, and new regulations relating to vehicles or driving. Here an outsider is brought into the program. He reaffirms the technique of producing something with a new look, but above all, communicates up-to-date traffic procedures. In addition, other agencies including State Compensation, resource people on insecticides, machinery, tools, etc., can be a valuable asset to safety programs.

What are the implications of the physical examination? A new employee is hired by the district. Later, he develops the early symptoms of pesticide exposure. An end result could be a damaged liver and kidneys, or he may experience a heart attack due to the heat of summer. Prior to being hired, a physical examination could have prevented these entities. It not only insures the well-being of the worker, but protects the district's liability, reduces compensation costs, and keeps mosquitoes from flying.

In safety then, you are indeed your brother's keeper. In a sense, you and I have two families—care for our people at work as well as our people at home. Know the rules of safety at work. Never let it be said that one of your co-workers was injured, because you were not aware of the precautions required on the job. Encourage your co-workers to discuss with you the hazards of their work. When you are receptive to the ideas of other workers, you tap a firsthand knowledge that will help prevent needless accidents.

Now consider this quotation, "An accident is an event which is unexpected. It does not 'just happen,' but is caused. Its cause may be an unsafe act by a person, or an unsafe physical condition, or a combination of both. Safety can be a habit. Let's try it."

OPERATIONAL PROCEDURES INVOLVED IN ANNEXING LARGE NON-CONTIGUOUS TERRITORY

E. L. Geveshausen
Southeast Mosquito Abatement District

Section #2330 of the California State Health and Safety Code provides for Mosquito Abatement Districts to annex areas that are not contiguous to the district boundaries, but within reasonable operating distance as determined by the Board of Supervisors of the county concerned.

On July 1, 1964, the Southeast Mosquito Abatement District entered into a contract with the City of Los Angeles to provide mosquito control for that portion of the city, known as the San Fernando Valley and the Wilmington-San Pedro or Harbor area of the city, an area of approximately 215 square miles. The need for this control work came about because the City of Los Angeles abandoned their City Health Department, who had previously provided this service. The health services were assumed at that time by the Los Angeles County Health Department which was required by law to provide the general health services for the city, but was not required to perform mosquito control.

The Los Angeles City Council, recognizing the needs for mosquito control in these areas, then indicated its desire to annex this area to an established district, entered into a contract with the S.E.M.A.D. to perform these services until annexation proceedings could be completed.

In view of the fact that there would be no revenue from this area until the following year, the cost for these services from July 1, 1964, to June 30, 1965, was paid by the City of Los Angeles. This contract was signed by the Los Angeles City Council and the S.E.M.A.D. on June 30, 1964, and the district assumed control on July 1, 1964.

The provisions of the contract called for the city to furnish to the district four pickup trucks with spray units plus office space and storage area for vehicles and supplies. The number of vehicles and supplies were not sufficient for the job at hand, which necessitated the leasing of more pickup trucks. These trucks were then fitted with pressure spray units and various other items to make them ready for operational use.

When the district accepted this contract, it also agreed to accept two of the employees of the Los Angeles City Health Department who had been doing this work for a number of years. To round out our work force, it was necessary to recruit and train twelve more employees. To facilitate the training, the district transferred a man from district headquarters to the valley area. As the foreman for the district, it was necessary for the first two months to spend considerable time in the area for training purposes and also for source reduction projects which were necessary for good overall mosquito control.

The S.E.M.A.D. has for a number of years used only righthand drive vehicles and a one-man operation. However, the vehicles we found necessary to lease were a standard lefthand drive which made for less efficient spray operations by our standards. This comes about because of the thousands of miles of gutters that have to be sprayed. Consequently, during the months of July, August, and September, it was necessary for the district to send ten to fourteen of our righthand drive jeeps to the valley on Saturdays to spray as much of the gutter water as possible to maintain adequate mosquito control.

At the time this contract was assumed, the S.E.M.A.D. also began a source reduction program in the San Fernando Valley. The largest project in the valley was the Los Angeles River behind the Sepulveda Dam in the

Sepulveda Basin, which is under the jurisdiction of the U.S. Army Corps of Engineers. Contact was made with the Corps of Engineers and a priority schedule was agreed on for the clearing of approximately one and one-half miles of willows, tules and other debris. A pilot channel was installed. This work was started the first of August and has now been completed, saving the district approximately 64 man-hours of labor a week. The Los Angeles County Flood Control cooperated by removing approximately 100,000 cubic yards of deposition from the upper paved portion of the Los Angeles River, saving the district another 24 man-hours a week.

The preceding are a few of the problems involved in annexing a large non-contiguous territory to an established M.A.D. There are other problems which would require two or three hours to describe fully.

In closing, I will say that the annexation of this area was accomplished at a final hearing at the S.E.M.A.D. headquarters on December 30, 1964, and the district is now in the process of purchasing a site for our valley depot and headquarters, together with the purchase of suitable vehicles and spray equipment for the job at hand.

THIRD SESSION (CONCURRENT)

ADMINISTRATIVE AND TECHNICAL SESSION

GARDNER C. MCFARLAND, *Presiding*

DEVELPING PHYSICAL ASPECTS OF MOSQUITO CONTROL

ROBERT H. PETERS
No. San Joaquin Co. Mosquito Abatement District

It is my pleasure to open the discussion relative to the field of physical aspects of mosquito control and perhaps to offer a broadened concept of this term which in years past we have referred to as "physical" along with the "chemical" and "biological" approaches in our field.

Webster defines physical as opposed to, or other than, mental. Perhaps this has been a factor in our past, inasmuch as we have allowed a separation to exist to a much greater degree than actually appears to be indicated.

It is my opinion that physical aspects of our program are lacking in motivation except when we incorporate a mental guidance which is forever based upon our ability to ask ourselves, "is this the best way to do the job, or accomplish our objective?" For too long a period of time, we have followed routine procedures of text book origin as relates to the physical aspects of mosquito control. In general, this was referred to initially as permanent control and then later for clarification, changed to mosquito source reduction.

In order to keep pace in this changing world where the complexities of increasing populations, consequent stricter regulations and resistant mosquito species have collectively made our task more difficult, we must recognize that our physical approach is not an isolated aspect of mosquito control. Rather we must realize that all of our methodology, including even insecticide application, is actually part of our physical approach to more effective mosquito control.

There is no longer basis for separation of our activities into phases of control. Even the changing of nozzles, the modification of a blower, or substituting larger tires on a vehicle, are actually physical aspects of mosquito control. In effect, all acts to meet our needs as time unfolds are truly to be construed as part of a coordinated effort rather than an isolated function.

Lest I give the false impression that I think we are standing still in California, let me indicate otherwise. It is my opinion that California mosquito control is second to none and that a continuous physical evolution is, and has been, under way wherein the collective representation of our agencies has time and again come up with newer and better ways of meeting our problems. My intent is merely to point out the fact that there are no physical limits in mosquito control, but rather that all functions within our programs are the combined result of planned action which is followed by an unlimited course of physical conclusion. This may indeed be another way of expressing our Conference theme "Program Balance."

Consequently, with this concept in mind, it is quite possible to surprise some and perhaps disappoint others when I say that this portion of the program will not be just on mosquito source reduction, but rather will cover the scope of physical changes and the methodology of mosquito control. This concept will not separate the following speakers, but rather join them in their desire to discuss ways and means of improving mosquito control in California.

It is my hope that general agreement will conclude from this preceding analysis, and now allow me to touch on what I think is a rather amazing summary of the effect of a program of physical change within our District. This year 1965 will mark a twenty-year impact of our cooperative heavy-equipment activities upon the major mosquito sources within our District.

During this time interval we have utilized two D-7 CAT tractors equipped with dozers and scrapers and for a portion of this period, two draglines and numerous innovations. Perhaps most extraordinary is the fact that this program of physical change has been almost entirely self-supporting, since we have attempted from the start to operate on a cost basis, payable by the owner of the mosquito producing problem. All projects have been the consequence of prior agreement rather than through forced participation.

Time does not permit the details of accomplishment during this twenty-year period. However, in general I can state that our equipment has moved in excess of three quarters of a million cubic yards of soil each year in attempting to solve our objectives. We have actually collected close to a quarter of a million dollars during this time in performing this most important work. This would be equivalent to almost a half a million dollars of work if done by private enterprise.

Needless to say, our Mosquito District has influenced the growth and development of our area to a profound degree. Regrettably I must acknowledge, however, that we still find our telephone is essential to discuss mosquito control with an occasional "customer."

THE LONG TERM APPROACH TO SOURCE REDUCTION

GEORGE R. WHITTEN
Delta Mosquito Abatement District

Many of you gentlemen attended the source reduction conference at Davis in November, which, incidentally, was one of the best we have had to date. The point which impressed me most at this meeting was that we do have answers to the technical problems which plague both the farmers and mosquito abatement districts in the field of soil and water management. The question which comes to mind is "Why don't we, or why haven't we solved our problems?" The answer is, of course, most of them are difficult, costly, and time consuming to solve. All the solutions require the expenditure of varying amounts of money and this must be justified by additional income potential. Time is needed. The land must appreciate in value sufficiently to warrant expenditure of monies necessary to assure maximum crop production and minimum mosquito production.

The so-called "good old days" when agricultural land could be bought for $5.00 to $20.00 per acre are gone, probably forever. Native land that is capable of being leveled and irrigated now sells for $200 to $500 per acre, if it is available. Leveled farm land sells for about $1,000 an acre, and if the land is planted to oranges, $5,000 an acre is not an unheard of figure. Valuable agricultural land with the tremendous income potential of our California land cannot be wasted on mosquito production. I am sure some of you gentlemen are saying to yourselves that orange land will take care of itself, but what about that irrigated pasture that was put in thirty years ago with mules and a Fresno scraper?

A man who paid $5.00 per acre thirty years ago for a piece of pasture, knocked off the high spots with a Fresno scraper, drilled a well, and was in the cattle business, is a difficult man to approach with a plan which might cost $100 or $200 per acre to re-level and generally bring his property up to modern standards for irrigation management. It seems a small problem to him that ten or fifteen acres are not producing because they are drowned out by over-irrigation or lack of proper drainage. After all, this land represents only a $50.00 or $75.00 investment, in his calculations. And yet, the man who pays $500 for that same acreage today knows in advance that he will have to invest additional money in order to make the land pay at all. The second man is unwilling to have even a portion of one acre go to waste because he simply can't afford it.

Many areas go along for years, and even decades, with practically no change in farming practices. Then a few of the more progressive farmers bring in new ideas from outside sources (perhaps from college, or some other farming community, or this may be sparked or supplemented by farmers forced out of the Los Angeles area by subdividers). The rest of the farmers watch these changes. Some will adopt the right way, others will be very slow to accept any change, and some will never change. (It would certainly aid the various districts if the farmer would follow Pope's philosophy, "Be not the first by whom the new is tried, nor yet the last to cast the old aside.")

At any rate, a district cannot create changes in cultural practices by itself, but it can have a definite influence on the rate of change by using all the avenues open to it. We have in the state of California some of the most progressive and efficient farmers in the world. Many of the good things they are doing aren't available to the farmers who are producing our major problems. Let's take advantage of their efficiency and use education to spread these beneficial ideas through newspapers, pamphlets and magazine articles. The district can also participate actively in helping to solve the farmer's problems by purchasing equipment and working with the farmer. This demonstrates good faith and generates confidence in the district's program.

Farmers are very suspicious people. They believe in themselves and in what they can see, but feel that government agencies are not to be trusted until they prove themselves worthy of trust. If we work with those farmers who are ready to invest money in physical improvements, others will follow the example set. This has happened time and time again in the Delta M.A.D. We have constructed a return system or a dairy drain return reservoir, and while we were in the process of construction, several neighbors stopped by to discuss their irrigation and drainage problems with us. This ultimately results in several additional projects.

In the Delta Mosquito Abatement District we are solving our problems one at a time. This is slow and we would like to move more rapidly toward our goal; so, if any of you gentlemen have a better solution, please let us know.

LARGE SCALE GRANULAR PARATHION PRE-TREATMENT OF A DUCK CLUB AREA IN THE COLUSA MOSQUITO ABATEMENT DISTRICT

Kenneth G. Whitesell
Colusa Mosquito Abatement District

The Colusa Mosquito Abatement District was formed in 1958, consisting of 140 square miles. A considerable problem to the District has been the Butte Sink, a 15 square mile area of Sutter County lying east of the District at the foot of the Sutter Buttes and composed mainly of privately-owned duck clubs. Beginning in August of each year, this land is flooded to attract ducks. Shortly thereafter, very heavy populations of *Aedes melanimon* move into the District's eastern boundary and subsequently into the City of Colusa.

In the past, the District has made some attempt to protect the City of Colusa by selective aerial adulticiding and thermal aerosol outside of the populated area, but the efforts have been largely futile due to the large area involved. Since the District budget was insufficient to control this area, it was obvious that control could only be attempted if the area were annexed. Annexation proceedings were therefore initiated, and in January, 1964, the Butte Sink became part of the Colusa Mosquito Abatement District.

The control method decided upon was granular parathion, applied as a pre-treatment. Accordingly, aerial photographs of the Sink were purchased and maps of the treatment area were prepared. The terrain was overflown while dry, with particular treatment problems being noted. The California Department of Fish and Game was notified of the proposed treatment and invited to monitor the control program to determine whether or not any deleterious effects upon wildlife occurred. They performed laboratory tests to determine if doves and pheasants could be killed by granular parathion prior to flooding of the area, and also observed the Sink after treatment for evidence of bird kill. Their findings showed that doves, but not pheasants, would accept the granules when penned in the laboratory, but field observations indicated no evidence of damage to doves.

A 450 hp. Stearman owned by Davis Dusters, equipped with a venturi spreader, was calibrated to deliver two pounds of 5% Durathion volclay granules per acre over a 50-foot swath, resulting in a dosage of 0.1 pound per acre of actual toxicant. The presence of tall willows and cottonwoods precluded the use of conventional ground flags, but some type of marker was necessary because of the lack of landmarks. Weather balloons inflated with hydrogen were therefore anchored to cords which allowed them to float about 175 feet above ground at spaced intervals. The pilot found that the balloons were visible for a considerable distance. These balloons when inflated attained a size of 3½′ to 4′ in diameter.

Preliminary estimates of the necessary amount of material were prepared on the basis of acreage measured from the aerial photos. The calculated area was 8,140 acres, requiring 16,280 pounds of granules; the actual total applied was 16,800 pounds. Two adjoining control agencies, the Sutter-Yuba and Butte County Mosquito Abatement Districts, contributed two and four tons of granules, respectively, since each was plagued by some of the mosquitoes from this Butte Sink area. The two M.A.D.'s also provided a man to assist with the balloon markers. The balance of the cost of granules and flight time was assumed by the Colusa M.A.D.

The control was generally excellent. Larval inspections after flooding showed that a miss had occurred at one site; hand treatment in a limited area took care of the problem. Subjective observations of the smaller numbers of *A. melanimon* in and near the City of Colusa were supported by the results of light trap collections. In late September and early October, 1964, counts were less than 10% of the 1963 levels.

THE CONTROLLED DISTRIBUTION SYSTEM FOR AGRICULTURAL AIRCRAFT[1]

Norman, B. Akesson, Wesley E. Yates, and W. E. Burgoyne
Department of Agricultural Engineering
University of California, Davis

For the past five years work has been conducted by agricultural engineers at the University of California at Davis in cooperation with Kenneth Razak, formerly Dean of the College of Engineering of the University of Wichita, Kansas, on a new concept for aerial application of agricultural pesticide chemicals, seeds, and fertilizers.

An aircraft has been developed which exploits the "boundary layer control" technique, which is a well known method for directing additional air to assist in maintaining normal air circulation about the wing of an aircraft, particularly under flight conditions of low air speed and high wing loading. Razak has adapted this to an agricultural aircraft by bringing the "boundary layer" air from a fan through wing ducts and discharging it rearward over the wing flaps and ailerons. This air also serves to entrain and transport dry materials such as fertilizers and seeds. A hopper and controlled feeder places the dry materials in the airstream from the fan, ahead of the wing ducts. The airstream then discharges the materials from the entire wing span (less the aileron portion) of the airplane. (Figure I and Figure II).

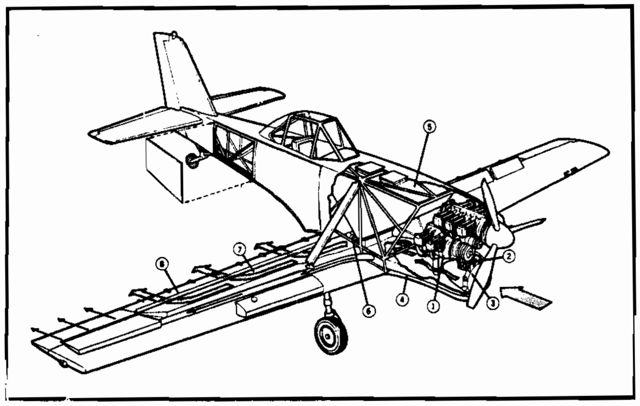


Figure I. Dry Materials Distribution: Hopper (5), Feeder (6), Blower (3), Discharge (7) and (8).

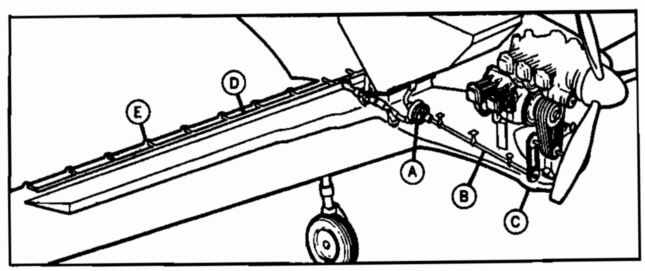


Figure II. Liquid Distribution: Pump (A), Boom (D), Nozzles (E).

Because this airstream can be controlled in direction, volume, and velocity (strength) along the entire wing span, it offers improvement in application of the dry materials by permitting (1) higher application rates per acre and (2) wider and more uniform material distribution.

Boundary layer air technique is particularly useful to agricultural aircraft in that it promotes aerodynamic stability for the slow flying, heavily loaded airplane. It also permits shorter take-off and landing distances for given loads, or greater load carrying ability. An engine separate from the propulsion engine is used to drive the air fan. This gives the aircraft an element of two-engine safety in that the plane will receive considerable flight power from the air ejected from the wing slot in much the manner of jet propulsion. This

[1]Support for this project has come in part from USPHS Grant Number EF-00281 and a California State Department of Public Health, Bureau of Vector Control grant.

gives an extended glide potential in case of propulsion engine failure.

While the controlled discharge feature is particularly useful for dispensing dry materials, it is also a significant factor in controlling liquid dispersion. The direction and strength of the discharged airstream which carrier the atomized liquids can be adjusted to direct these liquids into a uniform and desirably wide swath pattern.

The basic design of all agricultural aircraft follows the utility pattern, either biplane or monoplane, and in the latter case, with the wing in either low or high position. The Razak design employs a unique distribution system on a low wing aircraft and this system makes possible significant control of the distribution pattern.

The controlled discharge wing project started with swath width and distribution studies using a semi-span model wing mounted on a truck (Figure III). By 1964 the studies had advanced through two models and many test runs which had shown that the concept was sound and a significant advance in aerial application could be made by the design of a new aircraft. Razak formed a company for this purpose, and a prototype aircraft based on the model test program has been built and test flown (Figure IV).

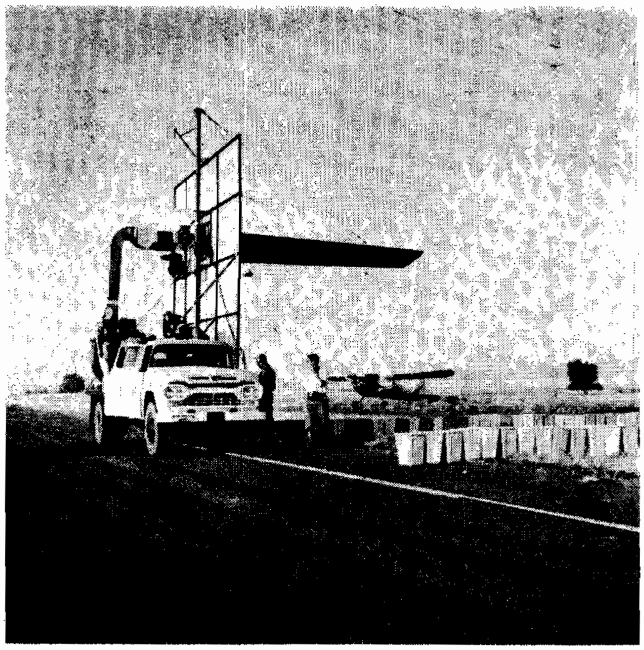


Figure III. Model wing mounted on truck. Plastic baskets for catching discharged dry materials.

Model testing was approached with considerable concern since a multiplicity of variables exist in an application system. These include at least the aircraft, the toxic material, the crop on which it is applied, and the pest to be controlled. The first wing was of 1/3 scale, and scale-up variables made it impossible to achieve a similitude of air circulation strength (as displayed by the shed vortex patterns) between the model and the aircraft to be compared.

Therefore a nearly full-scale model was constructed and again mounted on a truck for test purposes. This model is somewhat smaller than the aircraft and its maximum speed is 60 miles per hour so that only approximate similitude can be achieved. In use the prototype plane could be operated from 60 to 120 miles per hour. The following table indicates other variables which must be considered in order to obtain the basic similitude of air circulation strength between model and airplane.

Figure IV. Prototype aircraft in flight.

As evidenced by Table 1, the flap and aileron angles have to be increased significantly on the model to obtain circulation strength similar to that of the aircraft. This results in a larger coefficient of lift on the model wing since it is a little smaller than the prototype aircraft wing. To operate the model with these high flap angles, obtaining this coefficient of lift, boundary layer air must be used in order to prevent stalling (stopping of circulation) of the wing. The air velocity was adjusted on the model to about 25% higher than the forward velocity, or about 80 miles per hour. The air discharge slots were set to 3/8 inch on both flaps and the aileron for the total wing length of 214 inches, which gives a total discharge of 3900 cubic feet per minute.

In contrast to the ram-air powered venturi spreaders, the controlled discharge wing has an engine driven fan to give a positive air flow. This engine and fan must produce sufficient air volume and pressure to transport the large volumes of materials and to discharge them in uniform and wide swaths. An approximation can be made of the power required to operate the controlled discharge wing. On the model, for example, the 80 mph airstream at 3900 cfm is equivalent to about 2.0 horsepower.

However, fan and duct losses would greatly increase the actual power required at the fan. If we assume a 25% overall efficiency, 8.0 horsepower would be needed at the fan. This must be added to the power required to move the mass of material to be transported and to accelerate it to the forward velocity of the model. An estimate of the power required by the model can be made by taking a discharge rate of 10 pounds of material per second and 60 mph forward velocity, which is equivalent to 2.4 horsepower. If again we assume a system efficiency of 25%, the horsepower applied at the engine would be 9.6. Adding this to the air power required brings the overall power needed on the model to about 17.6 horsepower.

The full-scale aircraft is designed to provide for a 45-foot swath, 300 pounds per acre application rate of dry materials, at a velocity of 100 mph. This is equivalent to a 45 pound per second discharge rate, which, at 25% efficiency, would require about 120 horsepower. Adding the power for moving the air brings the total to 140 horsepower. At present, the fan engine on the prototype aircraft is powered by a 150 horsepower engine, and the main propulsion engine is rated at 290 horsepower.

Table 1: Variables concerning air circulation strength between model and airplane.

	Circulation strength (ft2/sec)	Velocity (miles/hour)	Wing angle (degrees)	Flap angle (degrees)	Aileron angle (degrees)	Coefficient of lift
Aircraft	495	63	13.7	15	0	1.96
Model	495	60	14	30	7	2.59

The Model Wing Test Program—Tests of the full-scale model have been limited to dry materials. Several types—granular, prilled, and seeds—have been used. Their characteristics are as follows:

Material	Pounds/cubic foot	85% between Tyler mesh
$(NH_4)_2SO_4$	64	10/20
Prilled urea	45.5	8/12
Rice	38.7	....
Granules	35.4	10/20
Granules	35.4	35/80

The individual test runs were evaluated by catching the discharged materials in plastic baskets set on one foot intervals perpendicular to the line of flight. The material so caught was transferred to small plastic bags, and these were weighed on a sensitive balance to measure the amount of material deposited at each station. The data obtained are plotted on the figures herewith. Runs were made only when wind velocity was low and as nearly in line with the flight path as possible. Velocity and direction data for the wind were noted with these swath distribution curves, as well as wing and flap setting angles, forward velocity, and fan data. The wing was operated at a height of 20 feet. At the point of material discharge in the run (a period of 6 to 10 seconds), a picture was taken of a manometer board where pressure data are shown for (a) seventeen spanwise, 25% chord pressure taps, (b) twelve static and total pressure taps on all ducts, (c) four static and total pressure taps at each fan discharge, and (d) one impact tube for forward velocity. These pressure taps indicate the aerodynamic operating characteristics of the wing. Also included in the photograph is a pressure gage which indicates the total wing lift during operation.

For tests with dry materials, the supply ducts were laid out to feed at six points (ejection stations) along the wing span, at 1, 4, 7, 10, 12, and 13 feet from the root. Each material was discharged from each point twice, once at full speed, and once at about 5 mph. The purpose of the low speed test was to establish the no-circulation discharge pattern, while full speed gave the pattern resulting from the combined wing circulation and air discharge acting on the material as it fell groundward. The pattern obtained from a single run, with the discharge at 13 feet, indicates that at 5 mph the material fell at about 14 feet but when operated at 58 mph the material fell at 17 feet.

From the plots of the individual runs, there was prepared for each material a curve to show the center

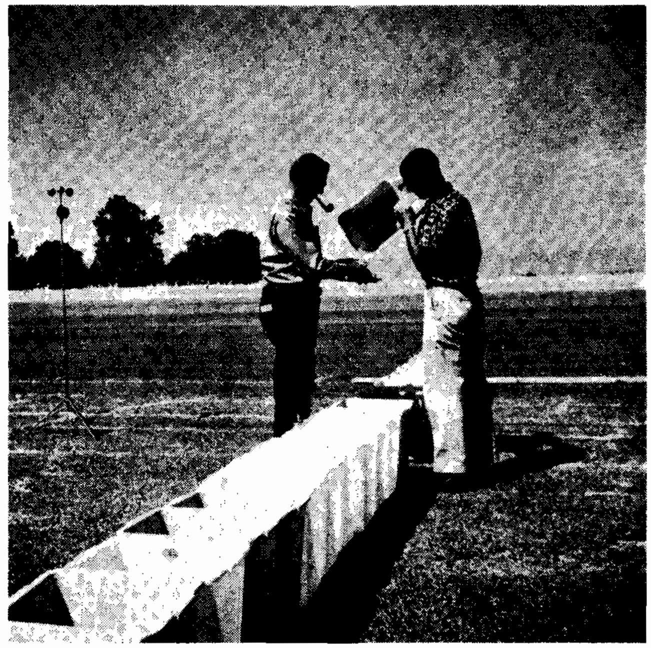


Figure V. Transferring dry materials from baskets to small plastic bags.

of mass versus ejection station. The curves for the 10/20 granules show that the center of mass at 5 mph shifts considerably toward the wing tips, particularly at the inboard station, being displaced approximately 5 feet at the 1-foot station, and 1 foot at the 12-foot station. This is because the airstream carrying the material from the wing is directed outward instead of straight to the rear. The 60-mph run data show that the interaction of the shed vortex and the discharge air have seemingly pulled the material inward near the root of the wing, but moved it strongly outward at stations 12 and 13 feet. This pattern is largely the same for prilled urea and ammonium sulphate. With rice, the 5 mph runs show outward discharge similar to that of the lighter, smaller materials. However, the vorticity effect at 60 mph is much reduced in comparison with the lighter, smaller materials; wing circulation thus appears to have little effect on rice distribution. The air discharge has a large component of outward direction. The effects of this outward motion combined with the vortex pattern become quite complex. There are several factors at work to produce this effect. Here it is evident that the action of the vortex field is largely downward at the root, gradually changing angle to an outward motion at the wing tip. Thus, in a time-distance concept, the material under influence at the vortex moves downward more rapidly at the root and strikes the ground sooner, with less lateral or outward displacement than is attained under air-discharge influence alone. Toward the wing tip the vortex influence is more outward and adds to the air-discharge effect, moving the material outward with less influence on downward motion.[2]

In summary, the truck mounted model wing has made it possible to obtain simulated data on a complex aircraft application system and has thereby assisted in the design of a new agricultural aircraft system. The test runs have helped to define some of the aerodynamic characteristics of the model wing in simulated flight and also to what extent the boundary layer control technique may be useful for agricultural applications. It is evident that fine particle sprays and dry materials (fine granulars and dusts) can be greatly influenced by the shed vortex pattern of the aircraft. However, coarse granulars, seeds and fertilizers are not affected as much by the shed vortex and require significant additional power to move them outward in order to obtain wider distrbution and coverage.

It is planned to continue further studies on the model as well as conducting certain runs on the prototype aircraft when it becomes available. The new aircraft offers promise for significant improvement of distribution uniformity from aircraft applications and increase in useable swath widths, as well as a potential for increasing productivity of the aircraft operator for all types of chemical applications and seeding.

[2]In the interest of simplification the bulk of the extensive data gathered during this work has been omitted. Professor Akesson has generously offered to make this precise and detailed material available to readers who have need of it.
(Editor's note)

DEVELOPMENTS IN WILDLIFE MANAGEMENT OF INTEREST TO MOSQUITO ABATEMENT AGENCIES

Ben Glading
Department of Fish and Game
Game Department Branch

When I was approached for this panel, they wanted me to talk about recent developments in wildlife management that would be of interest to you people here. Well, all I can say is that I don't think we have anything new but we have a great deal more of the same old stuff, which are more people, more price for land, more subdivisions, more automobiles, more aircraft, more insecticides, more this and more that.

I believe, though that there are some things in our field—some developments insofar as the way people are thinking about wildlife—that should be brought to your attention. Increasingly, we are finding that these pressures I mention are closing in on us. You people in mosquito control, in our interest, manage to across at the point of marshlands and wet lands, and of course this is one of our very critical pressure points, as it is almost your sole pressure point. In California we find that marshlands don't just happen; marshlands are on purpose. The very agency for which I work, the Resources Agency of California, recently set up a so-called wet lands task force and the idea is that not only is the Department of Fish and Game interested in wet lands, but every agency of state government dealing with resources is interested in wet lands. It has come to the time now where we can't think of wet lands as something that just happened. Virtually every acre of wet lands in California is on purpose, you might say—either by virtue of the fact that some private individual wants it to be wet lands, at least part of the year, or a public agency wants wet lands to be a part of public life.

Increasingly, another thing is happening in California: we used to think that our pressures as far as Fish and Game was concerned were coming primarily from duck clubs, duck hunters and people who wanted to spend the day in the marsh in the fall for the sole purpose of bringing home a big bag of ducks. This isn't true anymore. The California Department of Fish and Game has gone into a very intensive planning effort; we have hired as part of the planning team a number of national specialists in various fields. One of the specialists we have is the president of the National Audubon Society. This is an excellent indicator of what is coming in our field. What I'm leading up to is that this marshland is no longer dedicated to ducks alone. One time we thought that in the Sacramento Valley if there weren't enough sprig and mallards, well, to heck with it; we wouldn't even think in terms of any old thing like a widgeon. The old-time Sacramento Valley duck hunter called anything else except a sprig or a mallard a "funny duck." Now duck hunters treasure all ducks. The people of California are gradually getting to realize that all wild life is valuable and all marsh land that is capable of supporting wildlife is valuable.

This presents to us a rather unique problem. It is no problem for a wildlife manager to figure out how to raise and foster sprig; no particular problem for a wildlife manager to raise and foster mallard. Each of these species of waterfowl has a very precise, simple set of habitat requirements. But ducks, taken as a whole, have a fairly complex set of habitat requirements, and if we consider all the other associated marsh life—marsh birds, dowitchers, avocets, and what not, that people in the state or becoming interested in—here again we have an even more complex setup. Simply spoken, however, this setup is what nature has been providing all along. For us to duplicate it in modern life becomes extremely difficult.

I think many of you can figure what I'm leading up to—at one time we thought we had a fairly simple pattern established in the relationship to your problems here. To many people, mosquitoes naturally are not a part of modern life, and all of us have to work together to help reduce them. At one time in the not too distant past we were thinking in terms of late application of water—precise water level control—as possibly a large part of the answer. Now we're not so sure. And the reason we are not so sure is that in essence we are trying to maintain a complicated marsh for a complicated set of wildlife that has a complicated set of requirements which nature has been supplying all along. It is extremely difficult for man to modify this by cultural methods that we know about—water level controls, farming and what not. True, we're going to continue to explore these methods insofar as possible, but increasingly we have to remember that we are trying for society as a whole to provide these marshlands. An earlier speaker was talking in terms of land values, the increasing values of land; as you go to more highly priced land you get higher development. I think we all make the assumption that this high development means clean development in terms of level farming, asphalt, high buildings and what not, but I want to remind you that society as a whole feels there should be some element of wet lands, some element of marsh left, and believe me, marshes in terms of modern life are not "clean"; they are natural places that have to be left somewhat in a natural condition in order to realize their highest potential in a modern world. It's true that we're continuing to seek ways of meeting our other problems but this is the realization that we are coming to. Now what does this mean in terms of what we are talking about here? The lesson it means to me is that we can no longer rely on any one tool to get the job done. We can't rely on insecticides wholly, we can't rely on predators only, we can't rely on source reduction only; we have to look in terms of each marsh's need, and a refined technique for this marsh. We are dealing in lands that are dedicated for this purpose. We are paying in terms of right now. Ten years ago we were paying $250.00 per acre for waterfowl land. The price has now gone up to $400.00 or higher per acre. To indicate to you that it isn't just Fish and Game that is interested in this, under the State Park Bond Act—which I hope a lot of you voted for this last time —Beaches and Parks is buying marshlands and wet lands, not for people to shoot on, but for people to use in their ordinary recreation in the broadest sense of this word.

So the message I want to leave with you is that we have had good success using different methods in different parts of the state. I can quote some of them for you: right here today we saw a refined technique—Ken Whitesell, in a good marsh area—a most critical area—has managed to use insecticides by a refined technique in a way that as far as we are concerned hasn't done any apparent damage to the resources we're talking about. Oscar Lopp, using predators and biological controls, has done a satisfactory job as far as wildlife is concerned in his area. Pete Pangburn, in essence using a source reduction method, has done a very good job insofar as we are concerned. So what I'm saying is that no matter what technique is used, it has to be used as a part of the whole area ecology. You might say what we are talking about has to be constantly refined, and has to be used with the full realization that the basic purpose of this land—and if I step on any toes with this statement I'm still going to make it again—the basic purpose of the land is not mosquito control. The basic purpose of the land might be cities, might be agriculture, might be airports, might even be wildlife. The mosquito control is the thing that you do, realizing that the basic purpose of the land has to remain for the private land owner, and for the people of the state as a whole.

A COLEOPTEROUS PARASITE OF *HIPPELATES* EYE GNATS OF THE FAMILY STAPHINIDAE

LENORD D. MOORE
Coachella Valley Mosquito Abatement District

Investigations into the possibility of biological control of *Hippelates* eye gnats in the Coachella Valley have been made by Dr. E. C. Bay and Dr. E. F. Legner of the University of California at Riverside. Several species of hymenopterous parasites were found in California, Puerto Rico and Jamaica and were mass-reared at the University of California, Riverside, and at the Coachella Valley Mosquito Abatement District. In the spring and early summer of 1964 large numbers were released in the Jenkins date garden at Thermal. In September field exposures were made in an attempt to determine if some of these parasites were still present in this particular date garden.

One-pint plastic containers containing the gnat-rearing media developed by Dr. Mir Mulla, and seeded with *Hippelates* eggs, were set out in various places in the date garden with the top of the containers level with the surface of the ground. On the fifth day the containers were brought back to the laboratory and on the eleventh day the contents were washed through a Tyler Standard Screen and the gnat pupae were recovered by a flotation method. Examination under a microscope revealed that a number of these pupae had been parasitized by a staphylinid beetle. The parasitized pupae were placed on moist sand in a covered petri dish and left there until the adults emerged.

The first two adults to emerge were placed on a damp blotter in a covered petri dish but died shortly afterward. The remaining adults were placed in one-half pint containers with screened lids and containing gnat-rearing media seeded with *Hippelates* eggs and covered with sand. At the suggestion of Dr. Legner, crushed gnat pupae were placed in the containers as food for the adults. Since the supply of gnat pupae was limited, a different food material had to be found. Powdered egg is now being used successfully in the colonies. Subsequent field exposures were made and additional parasites were recovered.

In the laboratory the adults begin ovipositing in the sand or rearing media approximately three days after emergence. The eggs have been recovered by floating them in a 45% glycerine and water solution (a method suggested by Dr. Joseph Foulk of U.C.R.). They are oval in shape, measuring about 0.4 mm. long, 0.3 mm. wide and 0.25 mm. thick. They are transparent and the developing larva can be seen inside the egg. The eggs begin hatching in about three days. The first instar larva, measuring about 1 mm. in length, enters the pupa by chewing a small hole in the puparium. It feeds on the developing gnat until it is completely consumed. The larva, now measuring 3 mm., chews a large hole in the puparium and crawls out into the sand where it pupates in a cocoon of sand about 2.8 mm. long and 1.8 mm. wide. The adults measure 2 mm. for the males and 3 mm. for the females. The complete life history of this beetle has not been worked out at this time but is in the process of being done.

Specimens were sent to Dr. Ian Moore for identification but he was unable to identify the species. According to Dr. Moore, it is a member of the subfamily Aleocharinae and belongs to one of the tribes which is very poorly known, possibly the tribe Oxypodini.

From field tests made in the Coachella Valley, Dr. Bay and Dr. Legner have estimated the percent of natural control of *Hippelates* to be between 95% and 98%. This beetle, being native to the valley, has probably reached its peak of efficiency, but may play an important part in this natural control.

NOTES ON LIGHT TRAP CATCHES OF *CULEX TARSALIS* IN SALT LAKE COUNTY, UTAH

JAY E. GRAHAM

South Salt Lake County Mosquito Abatement District

and

IVER E. BRADLEY

University of Utah

An examination of the records of catches of *Culex tarsalis* mosquitoes taken in New Jersey-type light traps in Salt Lake County during the last twelve years shows that certain traps consistently take more males than females, while the reverse is true in some other traps. Table 1 summarizes the catches of *Culex tarsalis* taken in eight light traps during the past twelve years.

The ratios of male to female *Culex tarsalis* taken in traps which caught predominantly males as compared to others which caught predominantly females is shown graphically in Figure 1. This graph does not go beyond 1962 because of changes in some light trap locations in 1963. The Midvale trap was moved and caught less males at the new location. This change in the proportion of males to females was predicted.

The Midvale trap has always taken more males than females while the Riverton trap has taken more females than males every year of operation except 1955, when the trap was operated at a different location. A study was made of the Midvale and Riverton light trap sites to determine the factors which made one site more attractive than the other to one sex of *Culex tarsalis*. The sites were selected because the data indicate that these particular sites should show the greatest contrast in the factors responsible for the difference in catches.

The Riverton trap was located in an open area with no vegetation other than grasses, alfalfa and low weeds for a distance of several hundred yards. The trap was hung in a corral which contained livestock during the trapping period in 1961 and 1962 and part of the period of trap operation in some but not all other years. The Midvale trap was located in an old residential area under a large tree, with numerous other large trees and old sheds in the immediate vicinity. The trap and a large area around it was always shaded.

From these observations an hypothesis was developed that upon emergence, the males of *Culex tarsalis* found a cool, shaded area and remained relatively close to that area, while the females were ranging over open country, perhaps in search of a blood meal. The presence of sheep and cattle near the Riverton trap in 1961

Table 1. *Culex tarsalis* taken in mosquito light traps in the South Salt Lake County Mosquito Abatement District, 1953-1964.

	RIVERTON		MIDVALE		MURRAY		EAST MIDVALE	
Year	Percent males	Total trapped	Percent males	Total trapped	Percent males	Total trapped	Percent males	Total trapped
1953	23	31	70	74	67	58		
1954	30	71	66	62	45	85		
1955	59	37	71	70	57	70		
1956	32	22	84	87	70	103		
1957	42	19	84	131	60	91		
1958	48	86	60	262	49	132		
1959	39	76	60	90	56	127	46	25
1960	38	74	81	113	51	35	18	11
1961	18	61	91	206	62	42	38	13
1962	15	34	91	179	52	87	45	129
1963*	19	52	53*	43	72	54	46	46
1964	45	116	64	94	71	90	11	46
Average	36%		75%		59%		38%	

	HOLLADAY		CREEK ROAD		DRAPER		MEADOW BROOK	
Year	Percent males	Total trapped	Percent males	Total trapped	Percent males	Total trapped	Percent males	Total trapped
1959	31	13	44	25	56	50	51	88
1960	62	13	61	23	100	3	52	48
1961	63	8	63	27	46	13	0	8
1962	83	7	93	27	59	17	38	47
1963*	*		78	69	100	1	47	70
1964			71	34	77	54	46	50
Average	56%		71%		65%		46%	

*New trap location in Midvale; Holladay trap discontinued.

and 1962 is thought to be responsible for the increased predominance of females caught during those years. However, a flock of chickens has been housed near the Midvale trap since 1957 without having an appreciable effect on the sex ratio of *Culex tarsalis* taken.

This hypothesis was then tested against the data from traps located at Murray and at East Midvale. The Murray trap was in a shaded area, but the shading was less than that around the Midvale trap. The East Midvale trap was in the open, with more shaded areas close by than at Riverton. The ratio of males to females taken was the ratio expected if the hypothesis were correct. The Murray trap caught predominantly male mosquitoes, but not as much so as the Midvale trap. The East Midvale trap caught predominantly females but not so much so as the Riverton trap. These four light trap sites take relatively large numbers of *Culex tarsalis*, have more consistent patterns of sex ratios, and the data are considered more reliable than that from other traps in the district because of the numbers taken.

To further test the hypothesis, the light trap sites of the Salt Lake City Mosquito Abatement District were examined and predictions made as to whether more males or more females would be taken at each site. Examination of the light trap data showed that the predictions made for nine light trap sites were generally accurate.

Other factors also influence the relative numbers of male and female *Culex tarsalis* taken. For example, animals near the traps tend to attract more females, and the traps which caught predominantly females in South Salt Lake County (Riverton and East Midvale) had animals located near them. The Midvale trap caught predominantly males every year, and is located within ten yards of a flock of chickens. *Culex tarsalis* feeds frequently on birds but most of the mosquitoes trapped were males. Males of *Culex tarsalis* are thought to remain near the site of emergence. This seems to be substantiated by this study, but does not explain the ratios of males to females taken in traps in Salt Lake County. The light trap site in East Midvale yields predominantly females but is close to more and larger *Culex tarsalis* producing areas than the Midvale and Murray sites, demonstrating that the nature of the area around the traps is more important than the proximity of mosquito producing areas in determining the proportion of each sex trapped.

Summary and Conclusions

A study of light trap catches of *Culex tarsalis* in the South Salt Lake County and Salt Lake City Mosquito Abatement Districts shows that more males are taken in heavily shaded areas and more females are caught in open areas without much shade. The presence of animals and the nearness of *Culex tarsalis* producing areas to light traps has some influence on the numbers of each sex trapped, but the nature of the area around the trap is more important in determining sex ratios. Evaluation of light trap catches of *Culex tarsalis* requires consideration of the degree of shade and shelter in the vicinity of the trap, in addition to the other factors commonly considered.

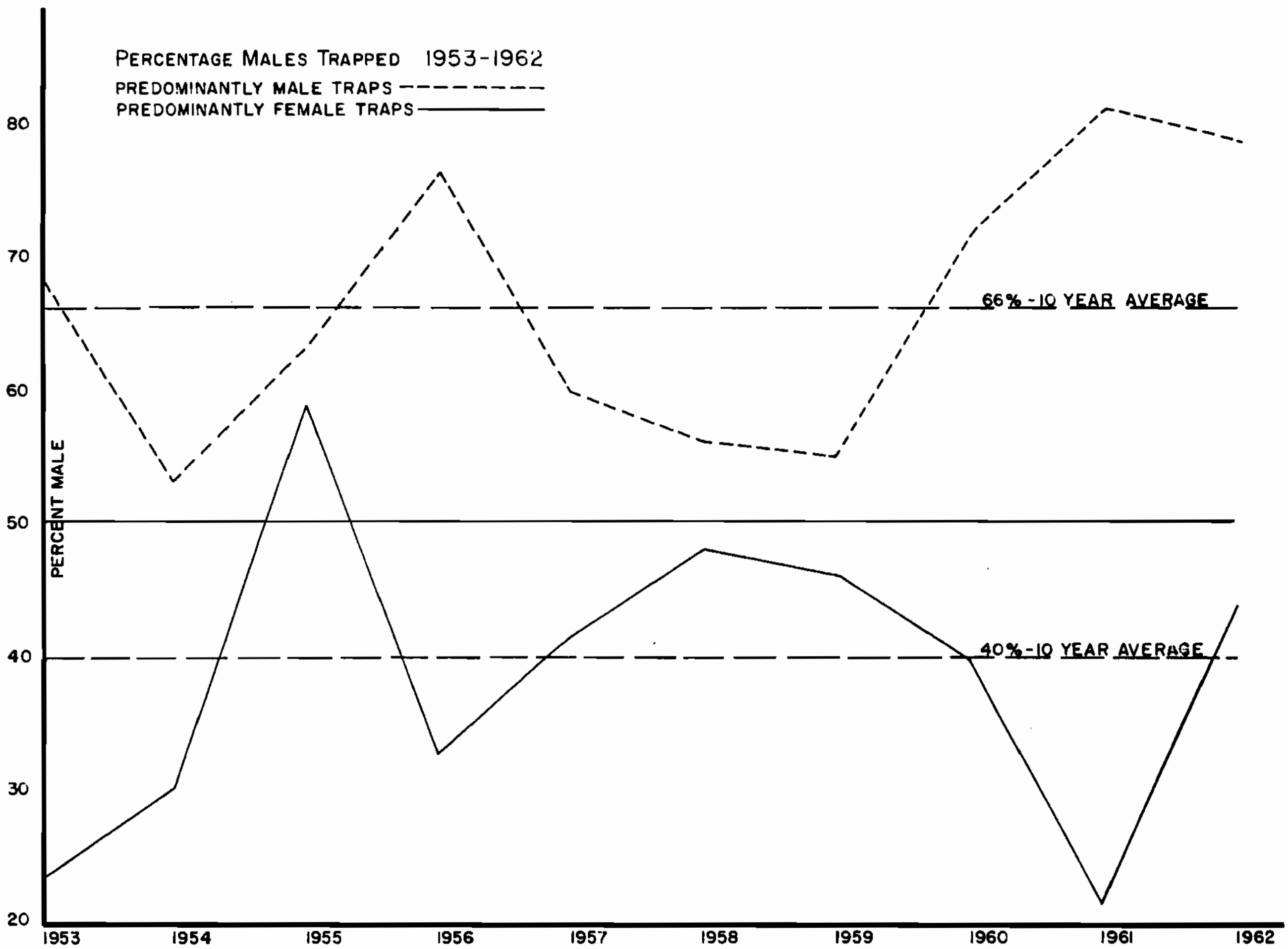


Figure 1. Percentages of male *Culex tarsalis* taken in light traps, 1953-62.

FOURTH SESSION

TUESDAY, JANUARY 26, 1:30 P.M.

PANEL: MOSQUITO RESISTANCE AND ITS IMPLICATIONS

LESTER R. BRUMBAUGH, *Presiding*

INTRODUCTION

W. DONALD MURRAY
Delta Mosquito Abatement District

Some of the districts in the southern part of the San Joaquin Valley have been leading the world in insecticide resistance, specifically larval resistance to the various insecticides used. As early as 1948 the Delta district had difficulty killing *Aedes nigromaculis* larvae with DDT. Tests run by Dr. Richard Bohart from U.C. Davis demonstrated clearly that the larvae were resistant to DDT. Neighboring districts also had this problem. In 1948 several districts shifted to toxaphene, which lasted until 1951, when it in turn became useless and, in 1952 we began using phosphate insecticides. In 1952 we used a little ethyl parathion, then began using a related material EPN. These phosphates worked a long time, but about 1958 or 1959 our neighbor, the Kings district, found resistance to ethyl parathion. That district shifted to methyl parathion, and the Delta district was forced to make this shift in 1960.

In 1963 methyl parathion was no longer universally effective. The Kings, Tulare and Delta districts all faced this situation together, and Baytex came into general or exclusive use within the next year or so.

Mosquito districts frequently suspect they have a resistance problem before such resistance has been scientifically proven. We may spray once, then again the next day, yet the larvae continue to swim. This is indicative of trouble. However, other things might have contributed: the spray from the plane may have skidded off an inversion layer, or the insecticide may have settled out too soon in the water, or heavy vegetation may prevent an adequate quantity of spray from reaching the water, etc. Therefore we do need the support of the field and laboratory tests.

Mrs. "Pat" Gillies has been making studies of mosquito resistance in the southern part of the Central Valley, from Merced south. She has been working in the Bureau of Vector Control under the guidance of Lawrence Lewallen since 1959. Her days sometimes are long–frequently she is out in the field 50 miles from Fresno by 6 a.m., and of course she must run through the tests in the laboratory after her return.

Don Womeldorf, as is Pat Gillies, is a graduate of Fresno State College. He began working with the Bureau of Vector Control in the area office in Fresno, then in 1963 moved to the Sacramento office. Don will review the remainder of the Central Valley, from Turlock north.

CURRENT STATUS AND FUTURE PROSPECTS OF ORGANOPHOSPHORUS RESISTANCE IN CALIFORNIA PASTURE MOSUITOES ABSTRACT

PATRICIA A. GILLIES AND DON J. WOMELDORF
California State Department of Public Health
Bureau of Vector Control

Surveillance of organophosphorus insecticide resistance in *Aedes* spp. was continued during 1964. A resistance threshold was established for each chemical by determining the LC_{50} of field populations that consistently caused control difficulties under normal operational conditions. At the present, resistance thresholds have been established only for *Aedes nigromaculis* (Ludlow); other *Aedes* spp. have apparently not yet developed definite organophosphorus resistance. The LC_{50} level for each unknown population was compared with the resistance threshold to show whether the larvae were susceptible or resistant, and also to predict whether or not a control failure might be encountered in the future.

Populations of *A. nigromaculis* with LC_{50}'s exceeding the malathion resistance threshold were found in the Pine Grove and Consolidated Mosquito Abatement Districts. Resistance has been known for some time from the Northern San Joaquin County, Kings, Tulare, and Delta Mosquito Abatement Districts. Resistance to parathion in *A. nigromaculis* was newly demonstrated in portions of the Butte County Mosquito Abatement District. It had been found in the Sutter-Yuba, East Side, Turlock and Fresno Mosquito Abatement Districts during 1963, and has been widespread for several years in the Kings, Tulare, Delta, and Kern Mosquito Abatement Districts. A single suspected *A. melanimon* Dyar parathion failure was reported from the Tulare Mosquito Abatement District in 1961. It has not been possible to find resistant *A. melanimon* in that area since then, nor has resistance in this species been confirmed elsewhere.

Populations of *A. nigromaculis* with LC_{50}'s above the resistance threshold to methyl parathion were found in a pasture complex lying in both the Butte County and Sutter-Yuba Mosquito Abatement Districts. The Kings, Tulare, and Delta Mosquito Abatement Districts have, for several years, been unable to use methyl parathion in a large area involving the three districts. Collections of *A. nigromaculis* with fenthion LC_{50}'s determined to be above the resistance threshold were made in the Kings, Tulare, and Delta Mosquito Abatement Districts during 1964.

In general, the development of parathion resistance in a pasture has been followed in turn by methyl parathion and fenthion failure when the insecticides were used in that order. It can be anticipated that this will continue to occur in the future. It can also be expected that resistance to a chemical will increase in any district now experiencing problems with it. Additionally, levels to various chemicals were found in several districts to be approaching resistance thresholds in localized areas. Malathion may fail in the Los Molinos Mosquito Abatement District; there are indications of impending parathion problems in the Tehama County, Corning, Colusa, Sacramento County-Yolo County, San Joaquin, and Merced County Mosquito Abatement Districts; methyl parathion failure may soon occur in the East Side and Turlock Mosquito Abatement Districts; and fenthion may not continue to give satisfactory control in a Northern San Joaquin County Mosquito Abatement District pasture.

It is planned to continue the organophosphorus insecticide resistance surveillance program in cooperation with the control agencies. The work will be expanded to include new chemicals as they become available for district use, to give additional emphasis to species and areas not yet adequately investigated, and to study the ecological factors relating to resistance.

Dr Murray: These two presentations represent the field studies. For much of the background to our resistance problems we turn to our University. For this afternoon, Dr. Metcalf, who was introduced to you yesterday morning, will analyze the background and indicate what the future may hold for us.

RESISTANCE IMPLICATIONS

Robert L. Metcalf
University of California at Riverside

I would like to talk about resistance implications. Perhaps I can serve as your conscience in what seems to be a very compelling matter to all entomologists. I began studying resistance back in 1947 and have worked with it more or less continuously ever since.

Having spent my recent professional life considering insect resistance, I don't think I'm quite as alarmed about it as a lot of other people seem to be. I see it as a continuing facet of the evolution of living things which is always going to be with us in one degree or more. For a long time we have had at the University of California at Riverside a program of testing new pesticides which includes simultaneous evaluation against susceptible and resistant strains. Up to the present there have always been some chemicals which are effective against these so-called resistant strains. Thus, having had access through our studies, particularly the WHO program of insecticide development which is aimed exclusively at resistant pests of importance in vector control, I have the greatest confidence in the worldwide chemical industry to produce compounds which will enable us to control resistant species.

An analogy to our problem is seen in the drug industry, for whom resistance by microorganisms is a very real problem. Here again, through the wonders of chemistry, it has always been possible to make some modification in the structure of a drug, and today there are literally hundreds of derivatives which are being used in medicine. Recently you recall what a triumph it was when penicillin was synthesized and reconstituted into various chemicals which proved effective against the normally penicillin-resistant strains of Staphylococci, Streptococci, etc. The chemical industry is able to do exactly the same thing for the entomologist or for anyone else who intends to use chemicals to control pests. It is up to us to take advantage of this capacity of modern science.

Recently I attended a National Research Council Symposium on insecticides. I don't think there was a single person among the forty who attended who wasn't convinced that pesticides would continue to be the method of reliance for the emergency control of pests as far as the foreseeable future is concerned. I think we must make the assumption that whenever pests exceed the normal biological fluctuation their ecological environment generally permits, or when people object even to these small levels, we will have to rely on pesticides as a primary emergency method of control. If we agree that this assumption is correct, we must find better ways to utilize the pesticides we now have, and we must in equally strong measure insure the future development of newer and better pesticides.

Dr. Mulla and I recently published in Mosquito News a paper in which we surveyed a large group of new chemicals that were very effective for mosquito control. Some of these are far superior to anything in use today. They are all new chemicals, not yet registered. They have a marvelous efficacy of performance against both susceptible and resistant mosquitoes, and some are far safer for the human user or the animal which may be accidentally exposed than anything now available.

This brings us to the crux of the problem with new chemicals—how do we get them into practical use? To do this it is necessary either to find a way through the use of public agencies and public funds to acquire the data which are needed for the registration and proof of safety of these compounds, or to convince the manufacturer that there is a sufficiently large material benefit to him to do this on his own. A third thing which is probably ancillary to these is that we should find a simpler method to register and to license these new chemicals. I believe that any federal, state or local agency which relies on chemicals for the control of pests is going to have to take the leadership in the registration and licensing of the chemicals it wishes to use.

In examining the resistance problem further, I would like to urge that we look for the silver lining. We should look for the benefits which might come from solving the problem. In the case of mosquito abatement districts, you expect an ever increasing standard of freedom from vexatious mosquitoes. But more than this, there is the challenge of the problem itself. Most of us have sat around and wrung our hands about resistance instead of being glad that it was there. It has been too easy in the past, because, when materials like DDT became available in 1946, it seemed like it was going to be a cinch to control pests of all descriptions. Possibly everyone looks back at how easy it was in the early days and assumes that was the rule and what happens now is the exception. But perhaps it isn't this way.

There is a very positive benefit here. Referring again to my analogy of medicine—you can't walk out on the street and ask the nearest passerby to treat you for a serious disease. Similarly, a person in a mosquito abatement district or other public control agency is not likely to be supplanted by the nearest man that wants a job. It is a highly technical, skilled profession. It is going to demand the best intelligence that can be developed, along with support from the Bureau of Vector Control, the University and others. This is perhaps one of the finest things about it—it will do more for the good of applied biology, or economic entomology, or whatever you may wish to call your control program, than almost any other thing that has happened. It certainly elevates the profession. It has become something which requires a great deal of skill.

This is something the medical profession has done so successfully. We can go back to the time when a medical degree was little more than a license to lance boils. Probably the first venture in mosquito control, when a man ran around and poured kerosene on water, was at about the same level of intellectual achievement. This is no longer the case, and we all ought to be glad about it.

Looking at pesticides themselves, I would rather refer to the "tolerance" of the insect rather than the "resistance." It is obvious that different kinds of insects vary greatly in tolerance. Some kinds are intrinsically less susceptible than others. DDT would never have been developed as an insecticide if it had been screened against the German cockroach, which it won't kill, or against various species of grasshoppers, against which it is completely ineffective. It did happen to be screened against mosquitoes, because it came along at a time when we needed something for the control of wartime mosquitoes and lice. If we look for materials which control insects, or to which insects are susceptible, instead of continuing to worry about the ones that don't work, I believe we will be in a much better frame of mind to attack the problem.

This is pretty elementary, but in any population of insects that has ever been studied, there are always some that are more resistant or tolerant to any of the pesticides than others. It was found in Africa, for example, with *Anopheles gambiae*, that over 6% of the individuals in a large wild population unexposed to dieldrin were completely resistant—or lacked susceptibility—to this material. It is obvious that it would take only a simple selection over a generation or two to reverse completely the percentages, so that we would be dealing with a preponderance of individuals which were not susceptible.

Culex fatigans (pipiens or *quinquefasciatus)* has been naturally DDT resistant ever since the first studies. DDT has never been effective in controlling it. I didn't see people wringing their hands about it—they investigated until they found some other things that did work. Slight modifications in some of the compounds available have already been shown to do wonders in making them effective against pests which have become resistant to the activity of the parent chemical. A good example is deutero DDT, a simple modification in which an atom of deuterium, which has an atomic number of 2, has been substituted for the hydrogen between the two rings of the DDT molecule. This has been shown to be extremely effective against *Aedes aegypti* which are quite resistant to DDT. It appears it will be developed commercially and used in the *Aedes aegypti* eradication program in our southern states.

The molecule of DDT with an orthochlor atom is an even more sensational product. This, by all the tests that we and others have made, is fully effective against a whole range of DDT resistant flies and mosquitoes. This is a simple chemical modification which could be cheaply and easily produced and certainly could be brought into commercial production if anyone believed it worthwhile.

There are many other things that can be explored. Recent work which has been done with synergists has shown that resistance, far from being a mystical and magical process, is really a very simple thing, something that happens to us whenever we eat many of the thousands of chemicals in plants or animals which are not particularly useful in human nutrition. We detoxify many of these chemicals which otherwise might be harmful. This is exactly what resistance changes in mosquitoes do. In resistant organisms the processes of detoxification have increased or heightened, sometimes not very much—perhaps only 1½ or 2 fold over the "normal." For every case of resistance that I know of, synergists have been developed which virtually restore, when used with the toxicant, the level of susceptibility to what it was in the first place.

The synergists act by interfering with or inhibiting the action of the detoxification system. We have not begun to explore what can be done by the use of simple synergistic materials in terms of practical use in pest control. For example, EPN with malathion has a synergistic action, and there are wonderful synergists for the carbamates.

Workers in mosquito control are particularly fortunate in another area, one that has interested me for a long time. They virtually control what goes on in a large area, in terms of insect populations. It seems to me that we have been remiss in not using this opportunity to study the basic aspects of applied ecology. You are in a position to start exploring many of the things that have been discussed theoretically: the effect of alternate treatment of pesticides; the use of combinations of different pesticides with different modes of action. It has been theorized, for example, from bacteriologic work, that resistance cannot possibly develop when three pesticides with different modes of action are used in combination. I don't know of any definitive experiments on this in insects, but knowing what I do about insects, I wouldn't predict that development of resistance could be prevented. But it would certainly be an interesting experiment to try. You could do it, quite sensibly and simply, while you are just doing your job.

Finally, I come to the intellectual challenge of resistance which, it seems to me, is one of the most important things of all. We cannot overestimate the innate capacity of organisms to go through evolution very rapidly under severely restricting conditions. This confronts everyone who is interested in controlling populations, whether they are microorganisms, mosquitoes, lemmings, fish, or any other living things. The resistance problem therefore ranks with the problem of trying to make application of what we know about the DNA code for the improvement of human genetics, or the problem of trying to do something about the world's population explosion, or the riddle of the nervous system and memory.

Resistance apparently can be developed to a great many things. People speak about microbial control, or the control with viruses. We know now that the myxomatosis virus which was used so successfully in Australia to control rabbits has lost a great deal of its effectiveness because the rabbit strains have rapidly developed resistance to it. This is what one would expect. This is an agent that probably produced about 99% mortality in the rabbit population when it was first used. The ones that survived are certainly those that had some innate biological capacity to withstand the toxic process of the virus.

Resistance has been shown in some cases to biological control by other insect pests. Resistance has been developed to the action of herbicides. This seems remarkable when you stop to think about it, but plants have this same ability, perhaps in a little slower degree than mosquitoes.

Therefore I think we have to face the basic problem —we are dealing with a capacity of organisms to change, and we will continue to be dealing with it as long as we are in mosquito control work. We should take the optimistic viewpoint that the more we learn about mosquito ecology and the effect of pressure of outside circumstances, the better we will be equipped to handle these problems.

I will close by saying: I think you are really lucky —you have an extremely interesting problem to work on. It is one of the most challenging biological problems of the age. Anything that you do that helps to solve it will not only help the people but will make you famous. It's a lot better than trying to control air pollution in the Los Angeles basin or the Communists in Viet Nam.

Mr. Brumbaugh: Thanks to all. Pat showed us that we had a problem, Don Womeldorf showed where the problem was, Bob gave us the solution to the problem, and Don Murray put the problem together. If you study history you can see what is happening—we are going to have this resistance problem with us, we must face it, we must use enough intelligence to start imagining, to start planning, we must get behind the University to give them the resources to enable them to give us answers; we must also get behind the Bureau of Vector Control of the State Department of Public Health to enable them to give us more help in the fields; and we as managers and trustees must be able to solve the problem in the cheapest and easiest way so that we can give our general public the best possible protection in public health.

FIFTH SESSION

TUESDAY, JANUARY 26, 3:00 P.M.

SOURCE REDUCTION CONSIDERATIONS

FRED A. COMPIANO, *Moderator*
San Joaquin Mosquito Abatement District

Mr. Compiano: Farm drainage is one of the most important and profitable practices of conservation farming and the most economical means of reducing or eliminating mosquito sources. On hundreds of farms, and on thousands of acres of fertile land, croplands too wet for profitable farming can, by means of drainage, be made to produce half to double as much as they are now producing.

Much progress has been made in farm drainage in the past years. For example, new equipment and high powered machinery have been developed. In some counties ordinances have been established so that our natural drainage channels will not be destroyed by means of land leveling or soil conservation. Mosquito abatement districts have also played a major part in farm drainage. Districts, then, should be well informed on the subject of farm drainage in order to present the problem adequately to the farmer.

First, I would like to state that personnel who are employed as source reduction specialists should have a general knowledge of the bionomics of mosquitoes. This is extremely important because this may affect the type of drainage you may propose. Also you will be able to answer questions asked by farmers regarding mosquitoes. This, in many cases, opens the door to the problem. Another important factor is a knowledge of agriculture including crops, soils, water, irrigation, water management, topography and engineering. Without this knowledge your approach would be a waste of your time and the farmer's tax dollar.

Planning a Drainage System—Only conditions in your own area can determine the kind of drainage you need and the method of doing the work. What is good in one place may not be good in another. Your soil, the ground slope, the crops you raise, and the value of land must all be considered. Neighboring farms must also be considered. An adequate drainage system often involves a number of farms, sometimes a whole watershed. In such cases, it is better to plan on a district basis rather than farm by farm. Before planning a drainage system, you need a detailed map of the area involved. Past costs for mosquito control of that area should be computed, and whether the area can produce enough to make it worthwhile to install a drainage system—because drainage is expensive.

The next step you need to consider is a proper outlet; that is, how the drainage water will be drained and where it will be discharged. Many drains have failed because of poor outlets. Plans for successful drainage include plans for controlling erosion on land, on ditches and spoil banks, and outlets. Outlets should be approved by flood control agencies, reclamation boards, and your local health districts.

Some simple drains can be located by inspections, and if there is ample fall, you can determine a workable grade with hand levels. But engineering instruments and techniques should be used in large areas. It is very important that a map be made showing boundaries of the area. Elevations should be established on a grid system at a minimum of 200 to 300 foot coordinates. This includes existing drains, all swales and watercourses, knolls, ridges, and elevations of possible outlets that may exist.

When survey data has been compiled, the drainage system can be laid out readily on a topographical map; grades and sizes of the drains are then determined, and cost estimated.

This information regarding drainage in large areas, of course, is perhaps oversimplified. Many other factors such as approval from boundary commissions, flood control reclamation boards, and county boards of supervisors must be taken into consideration.

Drainage on individual farms, in some cases, can be accomplished by installations such as return flow systems. Better water management may be most practical in some situations, and if drains are located adjacent to a natural drainage system, outlets could be used by pumps or gravity flows. But by and large this situation is not persistent throughout the entire area. Drainage principles, therefore, should be applied to the overall area rather than one or two segments of the problem.

In summary, drainage should be a cooperative venture with other agencies such as departments of public works, flood control agencies, and local and state health departments. Mosquito abatement districts, however, hold a unique position in farm land drainage. Surplus water from irrigated lands are small in relation, for example, to flood control, highway drainage and sanitation. In mosquito control, general economics are of a lesser hardship. Flows are smaller and are usually consistent throughout most of the year. Obviously then, many drainage problems may be readily solved through sound field approaches, basic engineering principles, and primarily, the development of good public relations throughout the district.

WEEDICIDING

RAY MCCART
East Side Mosquito Abatement District

In the last few years we have set up a regular program on weediciding. Under this, we weedicide barn drains, chicken drains and hog drains free of charge.

If this also includes a field drain, we charge one-half the cost of the material. For field drains, we charge for the material used. We do not charge for the labor. We spray city and cannery sewer ponds, charging for the materials used.

We have a four-wheel-drive Scout with a 100-gallon bean sprayer rigged up with a boom and hand sprayers. We hire two men during the summer to do the spraying.

Our standard spray during the summer is three pounds of Amino Triazole, five pounds of Dalapon and six ounces of X-77 per 100 gallons of water sprayed to wet. The cost is a little over $10.00 per 100 gallons of mixture. We have had very good results with this spray. We keep records of the amount of material used and the feet sprayed on each place. We find that the weeds should be sprayed before they reach six inches in height and sprayed a second time in 10 days. This should be repeated during the summer. It takes about four or five sprayings during the summer for good control.

An improvement district is a good example of how we work with organizations. The Ralston District has about 1,100 acres and 16,400 feet of drain ditches. We maintained these ditches in 1964 for $306.00 worth of materials.

This year, we are going into a program of sterilizing most of the places we have sprayed. There are a number of good sterilants, but we are using Atrazine. We are using it at the rate of 20 pounds per acre the first year and 10 pounds per acre the second. We found last year that Atrazine gave us a complete kill of weeds in the spring, but that the weeds came back at the waters edge in sewer ponds and in the bottom of ditches. We expect to spray these during the summer.

The cost of spraying with Atrazine, figuring 10 feet of bank sprayed, is about $0.01 per linear foot. This is cut in half the second year and could be less over a period of years.

We also found that a good control of the cattails is four pounds of Amino Triazole and six ounces of X-77 in 100 gallons of water. They should be sprayed to wet during the latter part of September.

TUESDAY, JANUARY 26, 1965, 3:00 P.M.

ANNUAL BUSINESS MEETING

Presiding: J. D. WILLIS, *President*

Note: A complete recording of the minutes has been duplicated and distributed to all members of the California Mosquito Control Association. Following is a summary of actions taken.

J. D. Willis: The business meeting of the California Mosquito Control Association will come to order. Our roll call shows that thirty-four corporate members are present, fourteen are absent.

I will now ask for approval of the 1965 budget as presented at the December 4, 1964, meeting of the Board of Directors.

It was moved by G. C. McFarland, seconded by L. R. Brumbaugh, and duly carried, that the budget as mailed be approved.

AUDIT REPORT

M. FREEDOM MEEKER
CERTIFIED PUBLIC ACCOUTANT
Chestnut and G Streets
Exeter, California
January 7, 1965

Board of Directors
California Mosquito Control Association, Inc.
1737 West Houston Avenue
Visalia, California

Gentlemen:

At the invitation of your Secretary-Treasurer, we submit the following recommendations regarding the handling of the revenues and expenses of the annual conference in your budgets and other records.

1. In connection with your transferring of sustaining members' dues and proceedings publication expenses and revenues to conference accounting (which we highly approve) we recommend that you establish an entirely separate budget for the conference. In preparing each budget, an unappropriated reserve can be determined by combining the surplus available at the end of the year (as near as it can be calculated at budget time) with the total expected revenues, and deducting the total budgeted expenditures. Without this determination, you can inadvertently budget more expenditures than your revenue and surplus combined. This could lead to an unintended use of taxpayers' funds for the conference, or vice versa. See comments in the Audit Report. I will be happy to explain this further to your Secretary-Treasurer, if necessary.

2. We recommend obtaining (in the same size if possible) journal sheets which have two more money columns, so that receipts and payments for administration and conference can be entered and totaled separately. Corresponding separation in the ledger is also advisable. This does not require any duplication of bank account, check book, or receipt book, nor any additional work other than totaling two more columns.

If there is any other way we can help, please let us know.

M. Freedom Meeker
Certified Public Accountant
Sincerely,

M. FREEDOM MEEKER
CERTIFIED PUBLIC ACCOUTANT
Chestnut and G Streets
Exeter, California
January 7, 1965

Board of Directors
California Mosquito Control Association, Inc.
1737 West Houston Avenue
Visalia, California

Gentlemen:

We have examined the balance sheet of the California Mosquito Control Association, Inc., as of December 31, 1964, and the related statement of surplus for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Our report includes the following financial statements:

Exhibit A—Balance Sheet, December 31, 1964

Exhibit B—Statement of Surplus, Year Ended December 31, 1964

Schedule 1—Schedule of Expenditures with Budget Comparison, Year Ended December 31, 1964

BUDGET PROCEDURES AND RESULTS

Your auditor applauds the efforts manifest in the minutes and in the 1965 budget, to more clearly distinguish between funds received for and applied to conference activities, and funds received for and applied to administration. This can easily be done in the budget and other records without another bank account. We are separately presenting recommendations. Reclassifying the dues of sustaining members and the expense and revenue related to publishing the conference proceedings into conference accounting is an appropriate step. Incidentally, since the first accounting segregation as of January 1, 1961, there has always been an available surplus of conference funds. Therefore, it is our opinion that during that time no taxpayers' funds could be considered to have been used for hospitality purposes at the conferences.

In the present audit, we have contributed to the accounting separation by allocating the savings interest (see note of Exhibit B) and by allocating the unappropriated reserve. Steps for preventing a recurrence of the negative unappropriated reserve are included in our separate recommendations.

Administration revenues were $515.01 more than the budget estimate of $4,768.00 and conference revenues were $842.00 more than the budget estimate of $2,425.00. Expenditure budget comparisons are shown on Schedule 1. Although two administration accounts were over-expended, there were balances in other administration accounts which could have been transferred. Similarly, the unappropriated reserve was greater than the over-expenditure for conference activities.

The Secretary reports 787 salable publications on hand, at $1.00 each.

OPINION

In our opinion, the accompanying balance sheet and statement of surplus present fairly the financial position of the California Mosquito Control Association, Inc., at December 31, 1964, and the results of its operation for the year then ended in conformity with generally accepted governmental accounting principles applied on a basis consistent with that of the preceding year.

Respectfully submitted,
M. Freedom Meeker
Certified Public Accountant

BALANCE SHEET
December 31, 1964

EXHIBIT A

Assets

Petty Cash		$ 43.69
Cash in Security First National Bank, Visalia		
Commercial Account		305.58
Savings Account		4,000.00
Fixed Assets (Note 1)		173.01
Total Assets		$4,522.28

Liabilities and Surplus

Sales Tax Payable		$ 6.52
Deferred Revenues (1965 Surplus) (Note 2)		535.00
Surplus invested in Fixed Assets		173.01
Available Surplus (Exhibit B)		
For Administration	$1,591.50	
For conference activities	2,216.25	3,807.75
Total Liabilities and Surplus		$4,522.28

Note 1: The "fixed assets" consist of a tape recorder purchased in 1961. The cost of a filing cabinet purchased several years ago is not known to the present Secretary.

Note 2: $5.00 is for 1965 administration and $530.00 for 1965 conference activities.

STATEMENT OF SURPLUS
Year Ended December 31, 1964

EXHIBIT B

	Estimate Budget	Derived From Activities General	Derived From Activities Conference
Balance Available, January 1, 1964		$1,643.26	$2,085.95
Add Revenues			
Corporate Member Contracts	$3,900.00	$4,012.00	
Associate Member Dues	48.00	54.00	
Sustaining Member Dues	450.00	575.00	
Sale of Publications	250.00	434.10	
Miscellaneous (Note 1)	120.00	114.91	88.00
31st Conference Registrations	825.00		$1,090.00
31st Conference Exhibits	300.00		725.00
31st Conference, General	1,300.00		1,457.00
Total Revenues	$7,193.00	$5,190.01	$3,360.00
Total Available		$6,833.27	$5,445.95
Deduct Expenditures (Schedule 1)		5,241.77	3,229.70
Balance Available, December 31, 1964		$1,591.50	$2,216.25

Note 1: $160.00 of the miscellaneous revenues was interest on the $4,000.00 in savings. Since about 55% of the savings represents conference funds, that per cent of the interest is allocated to conference revenue. No such allocation was made in 1963, although about $67.50 would have pertained to conference funds.

Schedule of Expenditures with Budget Comparison
Year Ended December 31, 1964

SCHEDULE 1

Classifications	Budget As Amended	Actual Expenditures	Under-Expended
Administration			
Advertising	$ 108.00	$ 108.00	$ -0-
Communications	300.00	610.30	(310.30)
Office of Secretary	1,200.00	828.23	371.77
Office Supplies	150.00	108.32	41.68
Proceedings Publication	3,000.00	2,478.80	521.20
Committee Expenses	1,200.00	720.20	479.80
Auditor	100.00	100.00	-0-
Fidelity Bond	-0-	-0-	-0-
Travel Expenses	500.00	231.61	268.39
Contingencies	-0-	56.31	(56.31)
Total Administration	$ 6,558.00	$5,241.77	$1,316.23
Conference, General Expense	$ 2,400.00	$3,229.70	$ (829.70)
Reserves			
Unappropriated Reserve, Admin.	$(146.74)	$ -0-	$ (146.74)
Unappropriated Reserve, Conference	2,110.95	-0-	2,110.95
Total Reserves	$ 1,964.21	$ -0-	$1,964.21
Total Budget and Expenditures	$10,922.21	$8,471.47	$2,450.74

REPORT OF COMMITTEES

(Reports were presented by all committees. Specific actions were taken as follows):

Research Committee, G. F. Smith, Chairman: The following resolution was moved by G. F. Smith, seconded by S. F. Cook, and duly carried:

RESOLUTION:

Whereas the California Mosquito Control Association has long recognized the need for increased research in mosquito control technology and has stated this need on many occasions; and

Whereas this need is continuing to become ever more urgent due to the continuing development of resistant strains of mosquitoes to insecticides in use and increasing restrictions on the use of these insecticides; and

Whereas the University of California is, in response to this need, proposing to increase its program on mosquito research as outlined in its 'Proposed Expanded Program of the University of California for the Control of Mosquitoes Affecting the Health and Well-being of Man'; and

Whereas the Joint Committee of the State Department of Public Health and the University of California on Research on Arthropods of Public Health Importance has endorsed and given its support to this proposal;

Now Therefore Be It Resolved that the California Mosquito Control Association in conference assembled does find that the aforementioned program is a well balanced program the pursuance of which would be of great value to the mosquito control agencies of this state and most strongly urges that this program be adopted formally by the University of California and that all actions necessary to put this program into effect be implemented as a matter of urgency to the continued success of mosquito control operation in the State of California.

Resolutions Committee: Fourteen resolutions were presented, after which it was moved by J. W. Bristow, duly seconded and passed, that these resolutions be adopted and appropriately implemented.

Honorary Membership Presentations: J. W. Bristow, trustee of Southeast Mosquito Abatement Distrist, moved, seconded by Mrs. Florence Sampson, trustee of Antelope Valley Mosquito Abatement District, and duly carried. that Honorary Membership be awarded to Alph H. Kirchen, former trustee of the Ballona Creek Mosquito Abatement District.

Miguel Berdona, trustee of Eastside Mosquito Abatement District, moved, seconded by J. W. Lane, manager of Northwest Mosquito Abatement District, and duly carried, that Honorary Membership be awarded posthumously to Roy L. Holmes, former trustee of the Eastside Mosquito Abatement District.

Contractual Payment Rate for 1965: It was moved by B. T. Whitworth, manager of Mosquito Abatement District No. 1, seconded by T. G. Raley, manager of Consolidated Mosquito Abatement District, that the contractual payments continue as in 1964. The motion was understood to be a recommendation to the Board of Directors. It was defeated by a vote of 14 yes and 15 no votes.

Nominations: The Nominating Committee presented the following slate of officers for 1965:

President:	William L. Rusconi
President-elect:	Oscar V. Lopp
Vice President:	Stephen M. Silveira
Past President:	J. D. Willis
Secretary-Treasurer:	W. Donald Murray

The Trustees reported the nomination as Trustee Representative of Carl W. Muller.

It was moved by E. C. Robinson, seconded by J. W. Lane and unanimously carried, that these nominees be elected to their respective offices.

Regional Representatives were selected as follows:

Sacramento:	Kenneth G. Whitsell
Coastal:	Dean H. Ecke
No. San Joaquin Valley:	Robert H. Peters
So. San Joaquin Valley:	Gustaf F. Augustson
Southern California:	Jack H. Kimball

Other Business: J. H. Brawley moved, seconded by L. R. Brumbaugh and duly carried, that the incoming President and Board of Directors be requested to formalize the Trustee Advisory Committee in accord with Article 4, Section 2, Item 2 of the Bylaws, and to include their names on the CMCA letterhead.

J. W. Bristow moved, seconded by H. R. Greenfield and duly carried, that the President be requested to appoint a committee of ten members, five of which shall be the five trustee representatives of the five regions of this Association, and the other five to be selected by the President, to consider an amendment or revision of the Bylaws.

PRESIDENT'S MESSAGE

J. D. Willis: This Association represents a large majority of the agencies involved in mosquito control in California. Only by being a unified group, standing together, will we be able to survive the changes in modern government and to remain independent local districts as we are today.

We are living in a dynamic and changing society. Mosquito control and the CMCA are an important part of this society and are subject to the same forces for change. Any organization, in order to continue to serve the purpose for which it was organized, must always be ready to adjust to these changes. However, change simply for the sake of change is not always profitable. Serious and considerate thought should be given before suggestions are accepted which affect the basic structure of the organization.

Those of us who are managers and other technical people involved in mosquito control do not always agree. And, in this respect, it will no doubt be impossible for the governing boards of all districts to agree. The members of this Association are from all areas of the State of California, and there is a great variation in their beliefs and their ways of operating their respective districts. There are a great many small districts with a small number on the governing board —many times only five members—and there are some of the larger districts that have twenty or even more members on their board. In some cases, board members are paid for attending meetings and receive funds for conferences and other meetings that they desire to attend. There are still some of the districts where the board members do not desire to be paid for attending meetings and do not have the time or do not desire to attend conferences. These are all local district policies and they are all basically right since this is their prerogative. But, in thinking of changes in our Association, those who finally have the responsibility for changes must certainly consider all of these differences, and, if this Association is to remain a strong association, we must have unified mosquito control at all levels. In the final analysis, they must be able to understand if and when changes are desirable.

The trustees of mosquito abatement districts have become more active in the affairs of the Association. I am sure that they still realize the need for managers and other technical people to operate their districts and, in some cases, they will realize for the first time the value of these technical people handling the affairs of a successful mosquito abatement district.

In 1964, your secretary, and I, as president, have continually tried to keep corporate members aware of the problems with which we are faced. By this time, all of our corporate members should realize our problems and should be in a position where they can give positive help to our Board of Directors whenever this might be needed.

I would like to thank all the members of the CMCA for having given me the opportunity to be president of the Association. It has certainly made me realize the value of an association such as the California Mosquito Control Association.

SIXTH SESSION

WEDNESDAY, JANUARY 27, 9:00 A.M.

C. DONALD GRANT, *Presiding*

A BRIEF REVIEW OF MOSQUITO AND VECTOR CONTROL ACTIVITIES IN THE PACIFIC NORTHWEST, 1964

GAINES W. EDDY
Agricultural Research Service
U. S. Department of Agriculture

Most of the more important mosquito and vector control activities in Oregon, Washington, Idaho, and Canada during 1964 were summarized at the 4th Annual Meeting of the Northwest Mosquito and Vector Control Association (NMVCA) meetings at Richland, Washington, November 17-18. Abstracts of the talks and papers presented at those meetings will appear in the proceedings. A brief review is presented below of some of the mosquito and vector control activities and of a few of the papers given during the meetings at Richland.

Oregon – One of the first and more important activities in Oregon during 1964 was the annual Vector Control Short Course held at the Marion County Mosquito Control District at Salem on March 31-April 1. The purpose of the course was to furnish information about or instructions concerning the use of new and currently recommended insecticides, equipment, and methods of application, as well as information about other matters concerned with the control of mosquitoes. During the session several individuals expressed the opinion that the use in mosquito control of all chlorinated hydrocarbon insecticides, except perhaps DDT, should be either abandoned or greatly restricted.

Further information on activities in Oregon during 1964 was given at the NMVCA meetings mentioned above. Participants from the U. S. Department of Agriculture, Entomology Research Division, at Corvallis included L. F. Lewis, C. M. Gjullin, and myself.

The data Mr. Lewis presented on field tests with mosquito larvicides indicated that American Cyanamid 52160 (0,0,0′,0′-tetramethyl 0,0′-thiodi-*p*-phenylene phosphorothioate, or Abate) is outstanding. It was equal or perhaps slightly superior to fenthion (Baytex). Mr. Gjullin reported on Division activities conducted in cooperation with the Bureau of Vector Control at Fresno, California. These tests involved applying low volume airplane sprays as mosquito larvicides. He indicated that the data would be published at a later date, in MOSQUITO NEWS. I summarized the data pertaining to the insecticides used for mosquito control during 1963. These data represented a compilation of results from materials used as larvicides, adulticides, and as prehatch treatments. The data were based on reports received from 15 districts or communities. A few reports, of minor importance, had to be deleted, because of lack of information. DDT represented approximately 80 percent of the total materials used. Also of the total, the City of Portland used approximately 38 percent. Most of the insecticides were applied as sprays against larvae. The materials and amounts used are as follows:

Material	*Actual pounds of toxicant used*
DDT	34,392
Parathion	4,112
Fenthion (Baytex)	1,737
Malathion	1,648
Naled (Dibrom)	184
Heptachlor	155
Carbaryl (Sevin)	150
Lindane[1]	111
Lethane	12
Diazinon	7
Dieldrin	5
Chlordane	4
Pyrethrins	1
Total[2]	42,518

[1]Includes "BHC."

[2]California used 331,370 pounds for same period. Total for United States (23 States) for 1961 equaled 2,266,210 pounds of toxicants.

Auge Anderson of Eugene read a paper entitled: "Some Special Problems of the Lane County Mosquito Control Service." One of the important problems there concerned the spread of *Aedes nigromaculis* (Lud.) in the Willamette Valley. He stated, "Eradication of this mosquito is of prime importance in that continued expansion of the species would be a serious threat to the development of Lane County." He presented some favorable data on using the mosquito fish, *Gambusia*, for mosquito control in log ponds and stated that 0.1 lb. per acre of fenthion was not harmful to the fish.

New mosquito and vector control districts in operation during the year included one at Klamath Falls, Klamath County, with Lester Hanna as the manager, and another at St. Helens, Columbia County, with Jessup Johnsen as the manager. The operations of the Klamath District were discussed by Mr. Hanna in a paper presented at the NMVCA meetings. Another District was established at Oregon City, Clackamas County, but will not be in operation until about July 1, 1965. The District is looking for a manager.

According to a personal communication from LaVerne Miller, State Mosquito and Vector Control Supervisor, there were 43 programs carried on in Oregon during 1964, including those of the organized Districts in the State.

Washington – Although several interesting and important papers concerned with mosquito and vector control in the State were given at the NMVCA meetings at Richland, only two will be mentioned here. Fred Bliss, Manager, Adams County Mosquito Control District, reviewed the history and past achievements of mosquito control in the Columbia Basin, and the current mosquito control activities and needs for future expansion of organized mosquito control in that area. His paper was entitled: "Vector Control in Eastern Washington—A Review of Mosquito Control in the Columbia Basin." According to Bliss, there are five organized districts in the basin but only three of these were active during 1964. In a letter to me he stated: "The taxes levied for mosquito control in the area next year will be nearly double the amount levied in 1964. The area covered by mosquito control programs is increasing substantially each year and the ultimate goal of providing mosquito control to the entire 500,000 acres of irrigated land within the irrigation project could be attained within ten years."

According to Roy Myklebust, Advisory Sanitarian, State Environmental Sanitation Section, by personal communication, there are also three other actively operating communities, one or two others being organized, and numerous cities in the State that practice some mosquito and vector control.

Dr. Robert Harwood gave a paper on "Research on Mosquitoes at Washington State University." An abstract of the paper is considered of sufficient interest to repeat here: "Primary research interest centers around photoperiodic responses using the mosquitoes *Culex tarsalis* and *Anopheles freeborni*. In *C. tarsalis* short daily photoperiod has been demonstrated to augment low temperature in the accumulation of unsaturated (primarily palmitoleic and oleic) fatty acids of adult females. These unsaturates no doubt aid cold survival.

"A sharp transition in photoperiod response (critical photoperiod) as determined by fat body development, can be seen in *A. freeborni*. Using these criteria a Washington strain (47° N lat.) has a critical photoperiod of 11-12 hours, a California strain (37° N lat.) has a critical photoperiod of 9-10 hours. This two hour difference undoubtedly relates to normal seasonal occurrence of low temperatures at these latitudes.

"Daily developmental and behavioral rhythms dependent on light and dark cues are seen in *C. tarsalis* but are less obvious in *A. freeborni*. In the former emergence of females occurs predominantly in the 8-4 hour period before termination of the dark phase. Oviposition of this mosquito occurs immediately after changes in light, probably a reflection of concurrent general flight activity.

"The basis of vertebrate host selection is under study using specially designed olfactometer. Such variables as temperature, carbon dioxide, and volatile factors will be investigated."

Idaho — There are no actively operating mosquito and vector control districts in the State. The work being carried on and the various problems in the State were reviewed at the NMVCA meetings by Robert Olsen, Chief, Vector Control Section, State Department of Health, in a paper entitled, "A Critical Look at Vector Control in Idaho." According to Olsen, the main problems involving domestic rodents, mosquitoes, ticks, and domestic flies are not receiving proper attention. He stated: "One mosquito district has been formed but no money has been levied for operation. Attempts to establish two other districts have failed. Some adult mosquito control has been attempted by various communities in the past."

Canada — Research and vector control problems in Canada were reviewed by L. Colin Curtis at the Northwest Mosquito and Vector Control Association meetings in a paper, "Recent Research in Canada." He discussed both laboratory and field work being carried on at Kamloops, Lethbridge, and Vancouver. Of particular interest was the research being conducted on the taxonomy and biology of black flies, host preferences of mosquitoes, and studies on basic factors of attraction and repellency in *Aedes aegypti* (L.)

Status of Insecticide Resistance — The resistance of *Culex tarsalis* Coq. to DDT in Oregon reported by Eddy *et al.* (1958. J. Econ. Entomol. 51:56-8) was apparently the first case of mosquito resistance reported in the northwestern states. No great spread of resistance has occurred in Oregon since then, which has probably been due in part to changes in insecticide use. Some slight resistance to DDT, dieldrin, and heptachlor has also been found in *Culex pipiens* and *C. peus* but not in other species. Several reports have been received on resistance of *C. tarsalis* to malathion, but so far as is known there has been no confirmed mosquito resistance to any of the organophosphates. Resistance in the Northwest is therefore apparently confined to Oregon and is limited to the resistance of *Culex* species to the chlorinated hydrocarbon insecticides.

REPORT FROM ARIZONA

Henry Greene
Arizona State Department of Public Health
Solid Waste Disposal and Vector Control Section

Members of the California Mosquito Control Association, friends, and distinguished guests:

It certainly was a pleasure to be invited to this meeting by Mr. Peters, especially since I am personally benefiting from the excellent papers which are being presented, and I also appreciate the opportunity that has been afforded to discuss specific problems and control measures that are of mutual interest in this field.

It has been of great interest to discuss what appears to be similar vector conditions with members of this association, and you have numerous achievements that have been accomplished in some of the California Mosquito Abatement Districts. We in Arizona would like to emulate that, should we be fortunate enough to obtain needed additional technical personnel, equipment, and materials.

It is hoped that through this conference we will be able to establish new working associations and relationships wherein there will be an opportunity to exchange technical data and improve programming to the benefit of the southwestern states.

In any event we in Arizona are actually in a neophyte stage of developing a total state program, and through our limited information, compiled and evaluated currently, we have a general idea of what the problem is and the type of program needed.

Programs in the past have been dictated by local needs and emergencies and must be subsequently considered basically as control operations only; however, throughout these emergencies we humbly demonstrated that considerable control could be obtained with minimum effort, equipment, materials, etc.

Vector control has only in the last year or so begun to reach a proper perspective in relationship to total environmental health throughout the state, and not until this year was it recognized to the extent that a new section was established comparable to the old division rating before the recent Arizona State Department of Health reorganization.

In the interim an education approach was attempted wherein maps were prepared to show the distribution of the principal mosquito vectors, principally arthropod-borne encephalitis vectors, throughout the state and their relationship to reported human and horse cases and geographically their relationship to the viral activities of chicken sentinel flocks placed throughout the state.

During the inception of this fact-finding stage, a seminar was conducted jointly with the Communicable Diseases Center to train personnel from health departments throughout the state in basic identification, insecticide formulations, and control measures. This, together with holding local workshops, has enabled us to obtain a more complete sampling of prevalent species throughout the state which, in turn, has guided our limited control operations more specifically.

About this time, we began a series of community communicable disease demonstration programs of which insect and vector control was one of the main targets in community environmental health, and it enabled us not only to further educate and train local personnel, but it presented an opportunity to bring about an all-level echelon of participation needed for total operations. Key municipalities and lay officials thereby would have a better understanding of their individual problems and control needs.

Numerous communities throughout the state participated in this program and it has afforded a nucleus in each of the specific geographic areas wherein we hope to build, from this nucleus, an opportunity to further these areas' activities.

During 1964 there were several cases of encephalitis reported in the state, suspected to be arthropod-borne, that caused much concern and at approximately the same time Arizona, believe it or not, had in some areas very heavy rains that resulted in several sections of the state receiving flood waters. Dense populations of flood water mosquitoes developed, particularly *Aedes vexans, Aedes dorsalis,* and *Psorophora confinnis* together with a marked increase in *Culex tarsalis* and *Culex quinquefasciatus* species.

As a result of these conditions, two sections were declared as disaster areas and a joint effort was made towards protection of the health of the people of these communities and to reduce vector-borne disease hazards. Equipment was purchased through the governor's emergency fund together with insecticides and, with various government agencies participating, extensive control measures were exercised. Other areas in the state that had received considerable rain and specifically those where the sentinal flock viral activities had been high were given assistance.

Insecticides used were set up on a revolving replacement basis with cities and counties to enable a stockpile of materials to be available for other areas as needed. Extensive newspaper publicity was accorded these operations in twenty-odd municipalities, and this we feel was instrumental in several health departments purchasing new equipment and materials, with others including this in their 1965 budget. This will, indeed, reduce local demand for use of the equipment from the state level. In some instances this is a joint city-county effort, wherein the transportation is furnished by the city and equipment furnished by the county. We feel that this ill wind did, so to speak, blow some good in that many of the areas for the first time realized the necessity for a good control program.

In Arizona, unfortunately, we do not have the legal authority by state statute to authorize the establishment of mosquito abatement districts; however, we may be able to benefit in the backwash of some sanitary districts, in a small way, in some type of insect and vector control operations. It is hoped that this year our program objectives for 1965 will include some of the following:

1. Survey and obtain more extensive entomological data throughout the state to determine densities of specific vector and insect species of public health significance.
2. Prepare area vector maps (flies, mosquitoes, etc.) to be used as program guides and control evaluations.
3. Integrate vector control program with solid waste disposal, sewage disposal, and water management and pollution control in community health activities.
4. Propose more extensive efforts to be exercised towards the elimination of vector breeding sites and media.
5. Promote, through local health departments, the elimination of improperly impounded water and encourage water drainage programs to eliminate mosquito breeding sites.
6. Aid in the planning of vector control programs with local health officials, to include state-wide survey, species collection, and identification to be used as a guide in determining needs and degree of control to be exercised.
7. Give technical assistance in type of insecticides to be used and methods of safe application.
8. Give direct service in control operations and proper handling of equipment, insecticides, etc., to help supplement inadequate local insecticide equipment and technical personnel.
9. Use state-owned fogging and larviciding equipment, as needed, to aid in control of insects and vectors, with materials being furnished locally.
10. Use state equipment and personnel in post-flood and disaster areas for emergency mosquito and fly control activities.
11. Through demonstrations with equipment, preparation of pesticide formulations and applications, newspaper releases, conferences with local civic and government groups, educate and train key local personnel in environmental preventive measures and also safety practices to be exercised in insect control.

12. Work with biology instructors of selected high schools in establishing special projects with advanced biology students in use of microscope, identification and collection of insects, and vector control.

13. Conduct local seminars for public health and other personnel to include biological familiarization, species identification techniques, basic chemical control, and vector-borne disease epidemiology.

Perhaps we are being too optimistic in our program objectives for it is felt that for the first time we have made a breakthrough and we are hoping to demonstrate the continuing need especially for mosquito control operations throughout the whole state.

REPORT FROM NEVADA

ROBERT NICHOLS
Nevada State Department of Agriculture

Clark County—Mosquito control in Clark County, by a governmental agency, was started in 1956. The initial work was by Clark County on breeding areas outside of municipal boundaries.

In 1959, the cities of Las Vegas, North Las Vegas and Boulder City initiated a program for mosquito control inside the municipal boundaries. Technical advice and control program coordination is through the Clark County Department of Agriculture.

Control work has consisted of larvicide treatment of accessible breeding terrain and adulticide treatment of residential areas.

With the assistance of the U.S. Health Service, Clark County Department of Health and other special services, surveys to determine species, distribution, breeding sites, etc., have been made at various intervals since 1955. Light trap surveys for population distribution are conducted annually.

The surveys have shown the need for a single agency coordinated program; however, due to the nature of the tax base the formation of a Las Vegas Valley Mosquito Abatement District has not been feasible. Under consideration at the present time is the formation of a single agency control program supported by County and Municipal jurisdictions.

Churchill County—In 1964 there was a great stimulation of public interest in mosquito control and formation of an abatement district. A public meeting was well attended and approved the circulation of petition for formation of an abatement district. These petitions are now being circulated.

The County Commissioners, City of Fallon, and Fallon Navy Air Station have expressed their interest and willingness to cooperate.

Lyon County—The Mason Valley Mosquito Abatement District was formed about 1958. Their operations to date have consisted of adulticiding the city of Yerington and doing a little larvicide spraying in ditches and ponds on the outskirts of town. Their maximum budget has been about $3,000 per year and this cannot be increased at present.

During wet years the District's operations were very ineffective and there was considerable public dissatisfaction.

The District had operated without a plan or much expert knowledge of mosquito control. Last year they secured the services of Tom Mulhern, Technical Consultant, Bureau of Vector Control, Fresno, California.

Mr. Mulhern spent two days surveying the District and prepared a plan of action. He found that most of the mosquitoes are the irrigation water type with a few *Culex* in some areas. He suggested that more emphasis be placed on prevention and less on adult control.

The District directors are very well pleased with his report and expect to take action on as much of it as possible this year. A major effort will be made to educate farmers in ways they can cut down mosquito populations by better irrigation methods. More emphasis will be placed on larvicide treatment of temporary ponds instead of relying on adulticiding of the town.

Washoe County—The Division of Environmental Sanitation of the District Health Department was instructed to form a mosquito control program in Washoe County, Reno and Sparks, in October of 1964.

The area has been surveyed on numerous occasions by the United States Public Health Service and personnel from the State of Nevada. The results of these surveys and additional investigative work have been translated into an operable program which will abate mosquito, fly, and rodent populations in the County.

In the control program, the entire City of Sparks, the entire City of Reno, and approximately 6,000 acres of Washoe County east of the Sparks-Reno city limits in the Truckee Meadows area will be involved. The program will be financed by the political subdivisions involved rather than through an assessment district.

There is programmed extensive use of aerial spraying using helicopters for the main wet-land spraying operations. Mobile truck units will be used for the remainder of the operations.

The program will employ two permanent full-time employees and up to four temporary seasonal spray operators.

There are numerous public and private agencies and groups concerned with the irrigation and drainage programs in the area, who have materially aided in the formation of the program.

THE CURRENT STATUS OF ORGANIZED MOSQUITO CONTROL IN TEXAS

DON W. MICKS
Department of Preventive Medicine and Public Health
The University of Texas Medical Branch, Galveston

As compared with states such as California, New Jersey, Florida and Utah, Texas is a comparative newcomer to organized mosquito control. It was not until 1949 that legal recognition was given to the fact that mosquitoes pose a threat to the health and well-being of the citizens of this state. The 51st Texas State Legislature provided for the creation, regulation and financing of mosquito control districts. Unfortunately, this enabling legislation applied to only those counties which border on the Gulf of Mexico, and there is no doubt that this limitation has hindered in a significant way the growth and development of organized mosquito control. Recently, after several years of effort by the Texas Mosquito Control Association, an amendment was obtained which permits any county in the state to establish a mosquito control district.

The first such district in Texas was set up in Jefferson County in 1950, followed a few years later by Galveston County. Interest in mosquito control at the county level had by then increased to the point where representatives of Brazoria, Chambers, Galveston, Orange and Jefferson Counties met in 1955 and organized the Gulf Coast Mosquito Control Association. Shortly thereafter, districts were established by Orange and Brazoria Counties. About this time it became obvious that the name of the state association was in conflict with its proposed scope and objectives. Accordingly, at its 1961 annual meeting, the Gulf Coast Mosquito Control Association changed its name to Texas Mosquito Control Association. This action provided an important stimulus to further association growth.

Aside from the matter of controlling encephalitis vectors in both epidemic and endemic areas of the state, by far the most important mosquito control problem facing the organized districts of Texas is control of the salt marsh mosquito, *Aedes sollicitans,* whose far-ranging migrations from the vast upper marsh areas of all coastal counties have significantly impeded the growth and development of this area. *Aedes taeniorhynchus, Culex fatigans* and certain other species also provide considerable discomfort and annoyance. By comparison, the control of these species is clearly secondary, requiring much less attention.

Since the inception of mosquito control in these counties, principal reliance has been placed upon adulticiding measures which are aimed first and foremost at the salt marsh species. Larval control has been and continues to be confined largely to *Culex* species in populated areas. Although this situation leaves much to be desired, it is dictated by less-than-adequate budgets in most of the mosquito control districts.

Adult Mosquito Control.—Only a few years ago, the four counties with year-around control programs used BHC dust applied by power dusters for adult mosquito control in both urban and rural areas. This insecticide proved to be effective for several years; then control failures occurred almost simultaneously in Galveston and Brazoria Counties. DDT was substituted and was effective for two seasons, after which both *A. sollicitans* and *C. fatigans* were shown to have a substantial level of resistance to BHC and DDT.

The mosquito control agencies in Jefferson and Orange Counties continue to use BHC. The Orange County district has relied upon BHC dust (5 per cent gamma isomer) as the only chemical control agent used in its adulticiding program in both residential and marsh areas. The "barrier-strip" technique, with the dust applied by aircraft, is employed in the latter situation. In spite of the fact that tests conducted in August and September of 1963 indicated some resistance by adult mosquitoes to BHC, and that in August of 1964, tests with larvae confirmed these results, mosquito control with BHC is reported to be satisfactory.

Adulticiding operations with ground equipment in Jefferson County employ BHC dust at the rate of 0.1 pound of gamma isomer per acre in all areas not suitable for air-spraying. The rate of application is adjusted upwards as the temperature falls below 70° F. Such dosage rates are reported to be ineffective at temperatures between approximately 60°-65° F. High humidity has been found to enhance operations. After several years of use of both fogging and dusting operations, the former method was discarded. Insecticidal dusting was found to be less expensive and to provide better coverage. Dusters of the Jefferson County District are now operated at speeds up to 15 miles per hour.

This district applies both malathion and Dibrom as aqueous emulsions by air, at the rate of one quart of liquid containing 0.1-0.25 pounds of malathion, and 0.025-0.1 pounds of Dibrom per acre, respectively, with a swath width of one hundred feet. Malathion is generally used in areas with sensitive wildlife. The only insecticide resistance of any significance is reported to involve *Culex fatigans,* which does not interfere with control since a larvicidal oil is used.

Following the development of resistance to BHC, DDT or both by *A. sollicitans, C. fatigans* and *C. salinarius* in Galveston and Brazoria Counties, malathion was substituted for all adulticiding operations. Malathion in fuel oil is fogged in residential areas, applied as five per cent dust in the more peripheral or rural situations, and as a water-based spray in marsh areas. It continues to be effective and has the additional advantage of low mammalian toxicity and short residual life when applied at the rate of 0.1-0.3 pounds of toxicant per acre.

Larval Control.—Unfortunately, none of the mosquito control district budgets permit the initiation of control measures against salt marsh mosquito larvae. The principal problem remaining is one of controlling *C. fatigans* in water of high organic content in ditches, such as septic ditches. Except for the control program in Orange County, which uses two-per cent malathion in diesel oil for larviciding open ditches and catch basins, the districts rely upon No. 2 diesel oil or related material with or without a spreading agent to kill mosquito larvae. This method is preferred by three districts because of the likelihood that the use of organic phosphates against the larvae would tend to speed up the development of malathion resistance.

Discussions and Conclusions

It is interesting that in spite of several outbreaks of mosquito-transmitted encephalitis in Texas in the relatively recent past, organized mosquito control was actually precipitated by the extreme annoyance and discomfort produced by seemingly endless invasions of salt marsh mosquitoes. These epidemics were not of sufficient magnitude or public impact to stimulate the formation of mosquito control districts.

Apparently, it was necessary for an epidemic of large and serious proportions to occur in a metropolitan area in order to create sufficient concern in the minds of the majority of citizens to stimulate action. An outbreak of St. Louis encephalitis, which was truly an epidemic involving 711 cases and 33 deaths, did result in the formation of the Harris County Mosquito

Control District. Parenthetically, this development followed by two years a meeting of representatives of the Texas Mosquito Control Association with Harris County officials. At that meeting the possibility of an encephalitis outbreak was pointed out in connection with a strong recommendation for a mosquito control program.

A by-product of this encephalitis episode was the formation of two additional districts in Calhoun and Matagorda Counties. In addition, Hale County, which has had a fairly lengthy history of encephalitis virus activity, voted to establish a mosquito control district but failed to appropriate the necessary funds. In any case, it is clear that epidemic mosquito-transmitted disease has its advantages as well as disadvantages.

It is indeed unfortunate that those Texas counties with active mosquito control districts have not seen fit to provide funds for source reduction work or for measures other than adulticiding, except in a token way. Only recently have we succeeded in organizing pilot studies in salt marsh water management. It is hoped, however, that the results of these programs will serve to convince the county authorities and the public that the soundest mosquito control is that applied to the aquatic stages.

THE ROLE OF GENETICS IN MOSQUITO CONTROL

George B. Craig, Jr., Ph.D.
Department of Biology
University of Notre Dame

About 100 years ago, in 1865, Gregor Mendel started what we know as genetics, with the publication of his famous work on green and yellow peas. That work was actually lost until 1900, so we date modern genetics from about 1900. Similarly we can date modern mosquito studies from about 1895 to 1900—the time of Ronald Ross and Walter Reed. Unfortunately, these two fields have gone divergent ways. Until very recently there has not been much connection between genetics and mosquito work, or indeed genetics and all kinds of entomological work. This is no longer true. The great genetical evolution that is taking over modern biology is affecting mosquito work as well. We know of very exciting things that are being done by plant and animal breeders, and more recently by the human geneticists in the medical school. Some of these things are beginning to happen in mosquito work as well. It is peculiar that this didn't happen a long time ago, because mosquitoes are wonderful material for genetical studies—they are almost ideal for a number of kinds of studies.

In genetical studies most of the work on mosquitoes has been limited to *Culex pipiens* and *Aedes ægypti*. There have been many chromosome studies, cytological studies, cytogenetic studies, chromosome patterns, etc., that have been done on *Anopheles*, but this genus has not been very good for studies of what might be called formal genetics—studies of mutants, 3 to 1 ratios, inheritance patterns, etc. On the other hand, *Aedes ægypti* and *Culex pipiens* have been very good for studies of formal genetics but perhaps not quite so good for chromosome studies.

A famous book published in 1960: "*Aedes ægypti*," by Sir Rickard Christophers, an impressive book with about 800 pages and about 1,800 references, states that no single gene mutants at all are known for *Aedes ægypti*. This is no longer the case. For both *Culex pipiens* and *Aedes ægypti* we know a great many single gene inherited characteristics—single genes inherited in a simple fashion such as blue and brown eyes in man. The productivity in the last 5 years has been almost alarming—these genes have been discovered rapidly and they have been easy to deal with. They are coming in faster now than we can keep them in laboratory cultures.

I would like to review some of these interesting peculiarities. The African *Aedes ægypti*, which occurs in the jungles, is small, black and silver, with the black and silver contrast very conspicuous. The brown and somewhat more yellowish form is *Aedes ægypti* as it occurs in the southeast United States. There is a mutant with no stripes down the back; another variety, *queenslandensis*, occurs in deserts in Arabia and Algeria; another mutant looks like *queenslandensis* but the proboscis is much paler and the wing scales are pale; another mutant, a silver form, is a subspecies on an island off Madagascar.

There are also larval mutants such as yellow larva, and a gene allele causing overproduction of pigment rather than underproduction.

Dr. McClelland has studied eye color mutants. He had three different genes—red eye, rust eye, and olive eye—and put them together in various crossing combinations. From such crosses he got some individuals that had colorless—or white—eyes. These white-eyed flies have poor vision. They can see light and dark, but their ability to discern surfaces is not so good as in normal individuals.

A miniature mutant has short wings, short proboscis and short legs. This is really a dwarf mosquito, in that the body is normal sized but the appendages are all short. It is a nice laboratory mosquito, because it doesn't fly well—just hops or jumps around. It rears very easily in the laboratory, but one doubts seriously that it would have much of a chance of becoming established in the field. We are particularly interested in this idea at the moment. You have heard about the activities of the *Aedes ægypti* eradication branch of the United States Public Healtth Service, and the leaders of this program have suggested that laboratory colonies in the southeast United States may be a hazard because individual mosquitoes may escape from the laboratories and become established in the field. There is a serious argument of whether this is likely, but at any rate we have suggested that if people want to work on insecticides or physiology or do other work where they need a laboratory colony in the southeast United States, why not use a white-eyed miniature mosquito. The larvae are quite normal, they respond to insecticides in the normal fashion, etc. This is a blind, crippled mosquito as an adult, and its chances of getting loose and doing any damage to the eradication program are truly negligible.

Another interesting mutant affects pigmentation. All the black pigment is gone, and the mutant is a bronze color. All the normally black structures in the cuticle and the scales are light bronze. We like this mutant very much because it affects all the stages in the life cycle. The bronze females lay bronze eggs; however, these eggs aren't very good. This is a lethal gene in that it causes sterility. The bronze female lays the eggs with the bronze egg shells, and embryonic development begins, but about half way through development the embryo inside the egg dies. Something goes wrong, we think, with the water relations. Since this is such an interesting mutant and we would like to keep it in very large numbers, we have developed a means of helping it along. We can tan this egg artificially by putting it in a solution of a tanning chemical, benzo quinone, which furthers the tanning of the egg shell and makes it look like a normal egg.

I might say that we have yet to get an embryo to hatch from this egg, but we have brought it all the way to hatching and I think we now have a dosage problem onlv—getting the right dose so that we can get an individual to hatch from this egg.

The idea here is that we have a situation much like diabetes in man. This bronze mosquito is caused by a single gene—just as diabetes is caused by a single gene in man. Normally it is lethal—individuals die from diabetes unless they have insulin. An artificial chemical must be supplied to them. It is similar with these bronze eggs. If we are around to tan the eggs for these mosquitoes, we may be able to help them complete their life cycle. If we are not around, then they cannot go any further. Here is a strain that is completely dependent on man. If they escape into the field, and start to lay their eggs, and nobody is around to tan them, they die.

Linkage maps have been developed to show the location of various genes on the chromosomes. We now have dieldrin resistance, and DDT resistance. We know that there are single genes controlling these characters, and they are not the same although they are close to one another on the same chromosome.

There is also a gene for susceptibility to filariasis on the first chromosome. McDonald in Liverpool has pound a single gene which causes *Aedes ægypti* susceptibility or nonsusceptibility to the filaria worms. Insusceptible individuals take in the worms, then they lay down a layer of pigment around them, and the worms are unable to develop in the mosquito tissue. We have found a similar thing for the transmission of chicken malaria. We suspect there are a lot of other genes of this sort that control the ability to transmit other worms, protozoa and viruses.

This brings up a very intriguing idea. Could we establish these nonsusceptible strains or genes in field populations. Could we lower a population of mosquitoes by normal control measures, then insert by mass releases these genes for inability to transmit disease, then let them go their merry way? Could we thereby convert a disease-transmitting population of mosquitoes from bad-guys to good-guys? In disease areas we wouldn't need to control them any more, except from the pest aspect, because they have been rendered harmless by converting them to nonvectors.

We are not dealing solely with morphological characters—eye color, differences in thorax, etc. There are many kinds of genetic characters in addition to the ones that can be seen. We have found single genes or fairly simple genetic mechanisms behind most of the characters we have studied. There are single genes controlling egg hatching, insecticide resistance, resistance to cold, etc. We have found that, for almost any characteristic we investigate, if we look long enough we can find some sort of a genetic basis behind it.

The matter of sex in mosquitoes has been particularly intriguing. In most animals there are sex chromosomes—xx and xy mechanisms—as is true in man. This isn't true in mosquitoes. Sex is determined, so far as we can tell, by a single gene. Dr. McClelland at the University of California at Davis has demonstrated this in *Aedes* mosquitoes. He showed that sex was a particular spot on one of the chromosomes; and it is the male, the father, which determines which sex the progeny will be. Half his sperm carry a gene we can call "big M" and half carry "little m." The female produces only one kind of gamete.

If this is the case, then how do we explain peculiar individuals we sometimes see—such as a gynandromorph? As an illustration, we have an individual in which the front end is female, and the hind end is male, with male claspers. One can do some very interesting studies with mosquito psychology in such situations. For example, in one such case an individual took a blood meal, following the inclinations of the female front end. When the blood reached the male abdomen, the male gut, which is not adapted for holding blood, broke wide open, and the individual died. So by following its front end, its hind end killed it.

We also have seen the reverse situation, an individual with a male head, male antennae and palps, and with a female hind end. Again one can do rather nasty things. Perhaps some of you have heard of experiments with tuning forks, in which the right pitch of fork will attract the males. Such an individual as we have just described is attracted to the sound, but then it fumbles about in a most pitiful fashion, because the front end tells it to come to the sound of the flying female, but the hind end cannot do a thing about it.

Another kind of gynandromorph is left-right, one side male and the other female.

By the use of marker genes, we can follow chromosomes and the patterns of inheritance. We have discovered how these gynandromorphs are formed. They occur when an egg is fertilized by two sperms. Two sperms enter an egg, and somehow the egg nucleus and a byproduct of the egg nucleus both get fertilized. Part of the fertilized egg then grows into a male and the other part into a female. This leads to an interesting situation—with the double fertilization one can have a gynandromorph with two fathers and one mother.

Another kind of sexual mixup is the individual that is in-between, neither male or female, but an intersex. There is a single gene, which has nothing to do with sex and is not on the sex chromosome, that controls this phenomenon. In such an intersex, the palps are neither as long as the male or as short as the female. The antennae also are in between.

In another phenomenon we have an individual with male genitalia with claspers, but there are also female cerci between the claspers. There are also the three spermathecae that are characteristic of a female. This individual is also an intersex. The gene which causes this condition, when the larvae are reared at normal temperatures, produces half males and half females. But the hotter the temperature, the further the males are turned into morphological females. Genetically an individual may be a male but morphologically a female.

We have been doing some crossing work between these males converted into females, and real males. No progeny has been produced yet, but we hope for success. If we can do this, we can have an individual with two fathers and no mother.

An absurd individual has been created by taking an individual larva with the gene for intersex and applying the high temperature stimulus very early in its development. Rearing is then finished at normal temperatures. Instead of converting all the way from a male to a female, the individual adult had an extra set of male genitalia coming out of the middle of the eighth abdominal segment. Such individuals have mated, using the back genitalia.

In most mosquitoes the sex ratio is 50-50. We found a gene which distorts the sex ratio, in favor of males. Something happens in the process of sperm formation. Normally half the sperm carry big M, half little m. In these peculiar individuals, most of the sperm carry M, the male determining gene, only a few carry m, the female gene. In this phenomenon which is called meiotic drive, there is an abnormal production of one kind of gamete at the expense of the other. This factor is passed from males to their male offspring, and we can get progeny with 110 male eggs and no or only one or two female eggs.

We have done some studies of introducing these males into populations of females that are sensitive to this characteristic. In a normal strain the results would be between 45% and 55% females. When we released the male-producing males into a batch of normal females, the sex ratio of females to males dropped very markedly. After ten or fifteen generations, the sex ratio was still strongly distorted. This didn't really duplicate what would happen in a normal field population, so to come closer to field conditions we set up cages and had continuous breeding rather than separating each generation.

A cage supports about 10,000 mosquitoes at all times. There is a dishpan of water, and females lay eggs on the edge of the pan above the water. We raise the water level every week or so, the eggs hatch, and generations go on indefinitely. We have run these cages for as long as five years, with continuous breeding.

We ran experiments releasing the male-producing males into cages with continuous breeding populations. Every week or two we collected a sample of eggs and hatched them out, counting the sex ratio. Twenty weeks after the start of the experiment, the sex ratio was still about 20% females. Since this time we have developed better strains, such as strains that produce only 5% females instead of 15% or 20%.

Of course this is very appealing. Can we mass produce this male-producing factor, release it into the field, and, without killing any mosquitoes, convert most of them into males? And—who cares about the males—except perhaps the females?

All this idea of mass producing individuals with particular genetic characteristics, and releasing them, is dependent on our ability to produce lots of mosquitoes. Until a very short time ago this didn't seem like a very good idea—factory producing mosquitoes. But it can be done! A lot of this work is being done in entomology right now, along with many other kinds of insects, putting biological engineering techniques to work in mass production.

Everyone knows of the dramatic success of the screw worm mass production and radiation sterilization program in the southeast United States. A production program was carried on on *Aedes aegypti* by the United States Public Health Service, with a minimum of facilities. Using a small room, about 10x20 feet, they were able to rear and release 1,333,000 males in a sixteen week period. This could have been expanded, but this was just a pilot project to see if it could be done.

The Public Health Service at Savannah, Georgia, used large laboratory cages supporting 5 to 10,000 mosquitoes each. Trays, about nine inches wide, seven feet long, and with about an inch of water in each, were seeded with about 7,000 first instar larvae. The water was maintained and the larvae were fed every couple of days until they reached pupation about six days after a hatch was started. By pulling the corks at the end of these trays and tilting them a little, the larvae and pupae all pour out into a container. With proper timing, we can get almost or all pupae and few or no larvae. By separating males from females, using a sexing device based on the size of the pupae, you can get all males or all females from one of these manufacturing processes.

In the U.S. Public Health Service work these pupae were irradiated and shipped to Pensacola, Florida, where they were mass released. Thus mass production of insects is a perfectly feasible affair. There are many prospects for mass release of individuals carrying various deleterious genetic factors.

GENETICS AND CONTROL OF *CULEX* MOSQUITOES

A. Ralph Barr
Bureau of Vector Control
California State Department of Public Health

ABSTRACT

The use of cytoplasmic incompatibility for eradicating *Culex pipiens* L. in California was discussed and preliminary findings on the search for a suitable strain were reported. The possibility of using lethals for control purposes was discussed and several such mutants in *C. pipiens* were described. Illustrations of a number of genetic markers in *C. pipiens* and *C. tarsalis* Coq. were shown.

USE AND APPLICATION OF MOSQUITO CONTROL MEASURES IN MALARIA ERADICATION

H. A. Rafatjah
Division of Malaria Eradication
World Health Organization, Geneva

Introduction

Control of malaria in the past has been based on attacking the parasite in man by drugs, preventing the contact between mosquito and man, and/or destroying, eliminating or incapacitating the vectors. The process has gone through many trials and changes in the past decades. Attack on the parasite in man alone as a control measure proved insufficient, and it was proved unjustifiably expensive and risky to attack the vectors alone without use of other means to reduce infection potentials or to wipe out the last cases of the disease. Based on this philosophy, a combination of the two methods has been used in various phases of the malaria eradication programme. The attack on the vector mosquitoes provides for the interruption of transmission due to the decrease of over-all longevity of the vector population, while the attack on the parasite helps to reduce the infection sources and to wipe out the last infective cases.

Mosquito Control Measures in Malaria Eradication

Attack on the mosquito vectors constitutes the principal control measure employed in a malaria eradication programme. Though used mainly against adult anophelines, it may involve the larval stages as well. Due to its complexity, larval control alone has seldom been the method of choice in a programme unless imagicidal operations failed to produce effective results. The malaria eradication programme is a gigantic undertaking, involving almost two-thirds[1] of the population of the globe, in most remote and underdeveloped areas. Therefore, complicated, highly technical and costly methods cannot be used for its implementation.

Imagicidal measures—Of all the imagicidal measures used in mosquito control operations, indoor spraying of insecticides is by far the most commonly used in malaria eradication. Limited fogging (peridomestic spraying) in conjunction with other control methods, is being used in certain programmes when indoor spraying no longer provides adequate control of vectors. Also in nomadic areas of southern Iran, dipping of nomads' tents in insecticides was tried as a means of controlling infective mosquitoes. Field experiments have also been made with DDVP vapour in African conditions. Due to high rate of air exchange in houses, necessitating large numbers of dispensers and the consequent high cost involved, these trials were discontinued. Further trials in other parts of the world, with different housing, climatic and epidemiological conditions, are being executed or planned.

Indoor spraying of insecticides—The indoor spraying of insecticides in the malaria eradication programme is not an all-out attack against all the vector mosquito populations. Nor is it meant to be a basic method of controlling mosquitoes. It is designed only to deal with a selective group, the infective population, for a period of time long enough to accomplish the eradication of the disease. In practice, however, only that portion of a population which may come in sufficient contact with the sprayed surfaces will be affected. Therefore, success in indoor spraying depends upon the habits and behaviour of the vector mosquitoes.

Indoor spraying of insecticides, as compared with other mosquito control measures, has the following advantages in a malaria eradication programme:

Simple: It needs no complicated techniques or equipment, nor specialized, highly-skilled manpower.

Practicable: It can be carried out almost everywhere and under virtually any conditions with high efficiency.

Effective: In most cases complete interruption of the disease can be achieved.

Quicker and shorter: Transmission is normally interrupted during the first year of spraying, and eradication may be achieved within a few years.

Cheaper: The comparative annual and total cost is generally considerably lower than the achievement of the same goal by other methods.

Experience has shown that when the spraying is of total, sufficient and regular coverage with an effective insecticide, it has been generally successful in interrupting transmission within the expected period. There have been setbacks however when: (1) the mosquito vectors were not domestic, i.e., they were outdoor resting (exophilic) or outdoor biting (exophagic); or (2) they became deterred or irritated by sprayed surfaces; or (3) there was physiological resistance; and (4) when other human, operational or administrative factors or deficiencies caused delays or setbacks.

Some of these changes have already occurred in certain parts of the world, rendering the indoor spraying the presently available insecticides almost ineffective. The present problem areas are very limited in extent; nevertheless, search for newer insecticides is actively under way and other available methods of mosquito control are under close scrutiny.

Other Mosquito Control Measures in Malaria Eradication Programmes

The Eleventh Report of the Expert Committee on Malaria paid special attention to the increasing need for the application of other methods of vector control in malaria eradication programmes, especially in areas where the response to residual insecticides in vector species is unsatisfactory.

The Committee further expressed that: "The present trend indicates a greater use of larval control in the near future and therefore urgent action is required."

The Committee recommended that: ". . . larval control be used more fully in special circumstances," and that "its further improvement be studied, especially in those areas that are refractory to residual spraying operations."

At the present time very limited larval control opera-

[1]Estimate does not include population from China (mainland), North Korea and North Viet Nam from which no information is available. *Wld. Hlth. Org. Off. Rec.*, 1964, *135*.

tions and source reduction activities are carried out in malaria eradication programmes. They are usually additional to the spraying operations because of their economic or technical benefits. A common practice in malaria eradication programmes is protection of large towns in malarious areas by the application of larval control measures in and around them. In such circumstances, these measures can be efficiently applied and supervised at a much lower cost than house-spraying. The most common measure used is larviciding, still carried out with compounds such as oil or Paris green· Application by hand or hand equipment is still the common practice. In most cases, power equipment or airplanes are yet to be introduced. Source reduction activities have also been carried out with most elementary methods and equipment. Judicious drainage and filling have been used on an extremely limited scale in a few programmes.

Instances where, for technical reasons, mosquito control measures other than spraying have been used are not very numerous. The programme in Jordan had to resort to larviciding and source reduction in addition to house-spraying in order to control *Anopheles sergenti*, a secondary exophilic vector, in the Jordan Valley.

The experience in Jordan Valley showed, however, that while in other areas spraying interrupted transmission within 3-5 years, larviciding could not produce a total interruption even after 13 years. The problem lay in delimiting the changing breeding areas, in applying the right dosage of larvicide and in maintaining the dosage adequately and evenly. Further, there were difficulties with organization and supervision in a changing situation. Many of these problems have been due to lack of experience and active interest in mosquito eradication by other mosquito control measures. In recent years, however, especially with the emergence of problem areas, serious attention has been paid to larviciding. A field trial was organized in El Salvador to assess the value of one of the newer insecticides (fenthion), and newer equipment in interrupting malaria transmission. The results, although inconclusive due to movement of population and other epidemiological factors, showed a marked superiority of fenthion to Paris green and DDT. This insecticide is already in use in larviciding operations in the malaria eradication programme in Nicaragua. Airplanes were also found to be superior to other equipment for dispersion of larvicides.

Outside the malaria eradication programmes, however, there has been growing interest in this field. Mosquito control organizations, particularly in the United States, have made the greatest share of the enormous progress achieved in this field. Newer and more potent larvicides have been tried out and better equipment and techniques have been developed. Extensive use has been made of aerial and ground power equipment to cut costs and raise efficiency. Use of modern excavating and earth-moving equipment has rendered source reduction a financial and operational possibility. The available experience and this wealth of knowledge should be used to improve similar operations in malaria eradication.

Need for planning--Unlike spraying operations, larval control measures cannot be applied to any situation and all conditions alike. The field is so large and the methods and material used are so numerous and different that their wide application and use in malaria eradication requires considerable and careful planning and preparation. The available methods should be carefully studied and tried before being selected and applied in a programme. Most important in planning the work is a knowledge of local conditions, which usually vary greatly from one area to another. The vectors and their biology, accessibility, etc.; the type of water; the condition and extent of the breeding places should all be appraised in detail. This implies that personnel in the field should be trained and made aware of the methodology and techniques involved, which calls for a reorganization of the training programme in malaria eradication, especially in the areas where these operations are to be carried out.

Larval control or source reduction activities are normally more costly than spraying. Therefore, in situations where they will have to be applied, the comparative cost of other suitable methods should also be considered.

Assessment of suitability of the present methods—The present mosquito control measures in operation should be studied and their suitability for application in malaria eradication assessed. They can be classified as: (a) physical methods, (b) chemical methods, (c) biological methods.

(a) Physical methods: These comprise source reduction such as drainage, filling, land reclamation, water management and impoundment, flooding, etc.

The use of these methods in malaria eradication operations, especially in agricultural areas, should be given first priority. The results of such operations are mostly of a permanent nature, and provide extra land and water for agriculture or recreational activities, and the work does not involve the risks and hazards of pesticide use. Fish and wildlife will be preserved, and in many cases the reclaimed land and the drained water can be utilized by the local inhabitants, thereby reducing the need for costly maintenance work. The methods would be especially popular, and would gain public support, in arid areas where the operational cost would be limited and the extra water useful.

Today there exists in the world market modern and highly efficient equipment for use in this type of work. Costs are reasonably low and well within the financial possibilities of malaria eradication services. In many countries this equipment has already been introduced and is in operation on road, dam, and other engineering and construction projects· In such areas the malaria eradication services may be able to make internal arrangements for partial use of the equipment. With the use of modern equipment, source reduction activities have now been tremendously accelerated. Breeding places can be flooded under millions of gallons of water, dewatered, filled in or drained in a matter of hours or days.

Even in programmes with no immediate problem with spraying, these measures should be used whenever feasible, to benefit from their apparent advantages.

(b) Chemical methods: Great progress has been made in the control of mosquitoes with chemicals. Newer and more potent chemicals have been developed and successfully used in actual field operations.

Also, better formulations and more efficient equipment for their application have been utilized.

In the field of larvicides, the reliance is now mostly rathion-methyl, and recently fenthion. So far, no major placed on organophosphorus compounds, mainly pa- problem of toxicity has been encountered at the dosages used. Fenthion is usually used in urban mosquito control due to its lower toxicity, while parathion is used in agricultural areas. These chemicals can be very conveniently used in malaria eradication larviciding work. Due to the low dosages employed, the larvicider carries only a small amount of concentrate, sufficient for a few weeks' consumption, which he mixes on the spot with water. Furthermore, they will not interfere with the indoor spraying, as none of these compounds are in field use for spraying in malaria eradication.

Similarly, use of chlorinated hydrocarbon insecticides for larviciding in the eradication programme may increase the chances of appearance of a resistant vector population, and are, therefore, generally contraindicated.

Paris green is still used in certain projects. However, newer formulations have increased its efficiency. Some of the vermiculite formulations of Paris green, especially the low release type, are used in some programmes. There are also a number of carbamate or phosphorus compounds under test which, when proven effective and safe, can be used for similar purposes in malaria eradication.

Malathion and Dibrom have been used extensively as in imagicidal fogging. They would be equally suitable for similar work in malaria eradication.

In the field of equipment, use of airplanes should certainly be promoted in malaria eradication where extensive breeding places exist. Newer models have eliminated many deficiencies of the past including high cost. Also, pilots and technicians are readily available and can be hired at a reasonably low cost.

Use of ground power equipment for larviciding in remote areas may not prove totally satisfactory. Their use however in areas with good roads and communication systems should always be considered.

Research work is also being carried out on repellants, attractants and chemosterilants which may have a place in control operation.

Serious attention should be paid to safe handling and application of these highly toxic compounds. Mixing and distribution centres should be so designed and operated as to eliminate the human element and thus reduce the chances of toxicity. Special equipment and measures should also be used for the protection of operators and inhabitants.

(c) Biological methods: These include use of predacious insects and other arthropods, fish and other vertebrates which are natural enemies of mosquitoes as well as pathogenic organisms affecting mosquitoes, such as bacteria, fungi, protozoa or viruses. They also include genetic manipulation or autocidal control. Except for fish which have already been used extensively in malaria control, the other methods have not as yet been used in wide scale mosquito control operations. In the field of agricultural pest control there have been cases of successful use of bacteria for control of pests. Studies on similar organisms are being actively carried out in the field of mosquito control. There is hope that these may lead to certan measures which could equally be used in malaria eradication operations, either alone or in combination with other methods.

Cultural methods have also been used in the past in malaria control operations by means of large scale changes of environment Some of these methods could and should be used in malaria eradication as a secondary measure to increase efficiency in operations.

Geographical reconnaissance—The principle of total coverage and need for geographical reconnaissance for the purpose is equally important in these activities, as in spraying operations. The work in larval control operations, however, may prove to be more complex and require much detail. Detailed, up-to-date maps of operational areas showing the location and extent of breeding places are essential· Aerial photography would be an asset and should be extensively used for this purpose.

Training—Training of staff and reorganization of training activities in malaria eradication is a subject requiring immediate attention. The staff, especially at field levels, should receive further training on mapping and map reading to be able to delimit breeding places and show on maps their location, extent and changes. They should also receive training on methods, techniques, material and equipment to be used in these operations. As knowledge of local conditions is essential for planning of work, the field staff should be made fully aware of this fact and instructed as to the type of information they should report to their higher offices.

Health education of the public, especially when using highly toxic materials, is an absolute necessity and should be included in the training of staff. Good public relations are just as important when the work is to be carried out on private property.

The training of higher staff at the supervisory or planning level should include specific information on various methods and techniques used, as well as material and equipment available in the market for the purpose. They should also be kept up to date on new developments in this field. Such staff should be provided with opportunity to visit advanced mosquito control projects in operation, using modern equipment, material and techniques.

Organizational trends—The organization of additional mosquito control activities in the malaria eradication programme greatly depends on the extent and types of measures used. In principle, these activities should be organized in close coordination with the activities of the programme to derive maximum benefit from the present facilities and manpower and to avoid duplication. Some of these activities could be conveniently integrated with other programme operations to save cost and manpower. Some others may be partially integrated and share some services and facilities with others. Examples of the latter are larviciding operations in which, through efficient planning, use may be made of the available field supervisory staff, transport and other facilities. Sterilization, genetic manipulation, or use of pathogenic organisms and other highly specialized methods may need separate units within the divisions of a malaria eradication programme. Whatever the organizational trends may be, it is essential that the actual application of work in the field be organized within the present decentralized framework of integrated field operations. Examples of these are the larviciding and source reduction activities presently carried out in malaria eradication programmes which are planned, organized, implemented and supervised by the divisions of field operations. In certain cases, however, it has been desirable to provide additional supervision and control from other units. In case of larviciding, for instance, entomological checks and assessments have been organized by an entirely separate division to increase reliability and efficiency·

Reporting procedures and processing should follow the usual pattern used in the malaria eradication programmes; namely, distribution to all sections concerned and analysis in the field offices for work correction.

Summary

1. The indoor spraying of insecticides is still the most economical, practical and efficient method of mosquito control for malaria eradication.

2. In the areas where, due to technical factors, the vectors' response to spraying is not adequate, other mosquito control measures are available and must be used to assist.

3. In recent years, there has been great progress in the field of mosquito control: newer, more potent chemicals; and more efficient equipment; and better methods and techniques have been developed.

4. Of the other operational mosquito control measures presently available, *source reduction, larviciding* and some *biological control* can be selected and organized within the malaria eradication programme.

PRESIDENTIAL MESSAGE

William R. Rusconi, *President*
California Mosquito Control Association

As the closing speaker of this, our Thirty-Third Annual Conference, I have a few brief comments I would like to present.

It is my belief that during the coming year our Association can expect new regulations on insecticides and I think we should now concentrate on being a part of setting up these rules so that they will work effectively, rather than wait and let the legislature enact regulations with which we as mosquito districts cannot comply and still do an effective job.

Now that our research program has been broadened we should not sit back complacently, but we should encourage this endeavor and give our full support to the program. The Association is very grateful for the research programs conducted between the University of California and the Bureau of Vector Control.

It is my wish that the trustees act as advisors for the Association in policy making, financing, and legislative matters.

As your new president, I would encourage the regional representatives to keep abreast of the activities of the Association and of all local area problems so that they can be properly presented at the Board of Directors' meeting.

I would urge the membership to channel all matters through the committee appointed by the Association so that proper action can be taken.

I would like to thank the program and local arrangements committees and all other individuals who were responsible for making this conference so successful. I now declare the Thirty-Third Annual Conference of the California Mosquito Control Association adjourned.