PROCEEDINGS AND PAPERS

OF THE

TWENTY-THIRD ANNUAL CONFERENCE OF THE

California Mosquito Control Association

AND THE

ELEVENTH ANNUAL MEETING OF THE

American Mosquito Control Association

AT

HOTEL STATLER, LOS ANGELES

AND THE UNIVERSITY OF CALIFORNIA AT LOS ANGELES

JANUARY 24, 25, 26, AND 27, 1955

Edited by

C. DONALD GRANT

CALIFORNIA MOSQUITO CONTROL ASSOCIATION, INC.

P. O. BOX 629

TURLOCK, CALIFORNIA

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OF THE

TWENTY-THIRD ANNUAL CONFERENCE

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CALIFORNIA MOSQUITO CONTROL ASSOCIATION, INC.

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ELEVENTH ANNUAL MEETING

OF THE

AMERICAN MOSQUITO CONTROL ASSOCIATION, INC.

Dedicated to

HAROLD FARNSWORTH GRAY, M.S., GR. P.H.

ENGINEER-MANAGER, ALAMEDA COUNTY MOSQUITO ABATEMENT DISTRICT (1930-1955)
LECTURER IN PUBLIC HEALTH, UNIVERSITY OF CALIFORNIA (1930-1952)

HONORARY MEMBER

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(1) John Manweiler and adversary. (2) Dr. L. W. Hackett presents the "Book of Letters" to Harold and Harriet Gray. (3) Harold F. Gray and Richard F. Peters in exhibit room. (4) Two generations of mosquito controllers, John and Oliver Stivers, receive commendation from Rolly Dorer. (5) Tribute to Harold F. Gray: S. F. Dommes, Jr., Harold, Dr. L. W. Hackett, Richard F. Peters, Mrs. Gray, Don Collins. (6) Commander John M. Hirst announces the publication of AMCA Bulletin No. 3 by Helen Louise (Trembley) Durkee. (7) Dr. Malcolm H. Merrill gives an opening welcome for the California State Department of Public Health, C. Donald Grant presiding.


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PROCEEDINGS AND PAPERS OF THE TWENTY-THIRD ANNUAL CONFERENCE OF THE

California Mosquito Control Association

AND THE

ELEVENTH ANNUAL MEETING OF THE

American Mosquito Control Association

FIRST SESSION 9:30 A. M., MONDAY, JANUARY 23, 1955

SIERRA ROOM, HOTEL STATLER

The meeting was called to order at 9:30 a.m. by CMCA President C. Donald Grant of San Mateo County Mosquito Abatement District.

Mr. Grant: It is gratifying to see such an excellent turn out and so many people whom I met in the East last year that have come out here to California this year. We also are gratified that the weather has turned out so nicely with sunshine; that's for the Southern California members. They are a bit unhappy about the wintry chill of the December weather, but they do have warm weather here at the present.

We are hoping that you will enjoy yourselves here, and especially do we hope you will enjoy the many fine speakers we have on the program today. I would like to call upon Rolly Dorer, President of the American Mosquito Control Association for an announcement.

Mr. Dorer: Last night, at the Board meeting a petition was presented to elect Harold Gray an Honorary member of the American Mosquito Control Association. This is being done in connection with the celebration of Harold Gray at this meeting. It is to be kept a secret.

According to our By-Laws, it is necessary first that a petition be presented to the Board of Directors for action; then be again presented to the entire membership at the convention. The matter was unanimously approved by the Board last night. At this time I would like to call for an expression from the entire membership. With that in mind the chair will entertain a motion to that effect.

Mr. Peters: Mr. President, I move that Harold Farnsworth Gray be awarded an Honorary Membership in the American Mosquito Control Association for his outstanding services in mosquito control.

Dr. Rees: Mr. President, I second that motion.

Mr. Dorer: The motion has been made and seconded. Is there any dissension? Are you ready for the question? All those in favor say Aye—"Aye"—all those opposed—"Silence"—will the secretary record that the vote was unanimous in favor of the motion. That's all the business I have, Mr. Grant.

Mr. Grant: At this time it gives me great pleasure to introduce the man who is the Director of the State Department of Public Health and who has been most intimate with mosquito work for many years. I introduce to you, Dr. Malcolm Merrill.

Dr. Merrill: It is a real pleasure and honor to serve as welcoming spokesman for the State of California. We Californians greet you and extend you every cordiality during and following this significant Conference. Judging from the array of fine papers on the program, as well as the social functions scheduled, the prognosis points to a rewarding experience.

Our State, and the Department of Public Health in particular, is deeply aware of and appreciative of the important field of endeavor to which you are individually and collectively dedicated. Mosquitoes are indeed one of California's important problems. Like our growing population, and industrial expansion and our water resources development, mosquito problems are also showing conspicuous gains. Our salubrious climate is agreeable to mosquitoes as well as people!

In looking backwards for a moment, it is truly remarkable to realize how far mosquito control has advanced in only approximately sixty years of knowledge and activity in this field. 1955 is our "Golden Anniversary" year in California, since it was just fifty years ago that the first mosquito control demonstration was performed by Professor H. J. Quayle of the University of California on our San Mateo County salt marshes. The transition which has taken place in the years since 1905 is truly worthy of mention.

Briefly, California has seen several episodes of mosquito problems in this short span of history. The first problem met by the public was an economic one, in which salt marsh mosquitoes in the San Francisco Bay area actually threatened curtailment of real estate developments. Almost simultaneously the control of malaria presented a direct public health problem. I should like to recognize the great contributions of the late Professor W. B. Herms, of Harold F. Gray, our honored guest at this Convention, and of Provost Stanley B. Freeborn of the University of California, Davis, in helping to curb this disease. Now after fifty years of mosquito control in this State, only forty of which have been on an organized basis, we can boast about the virtual abatement of mosquitoes on most of our coastal and inland streams and marshes and the near disappearance of malaria. To be sure, lest mosquito control workers be given exaggerated credit, agricultural reclamation and flood control activities, as well as improved housing, have undoubtedly assisted to some extent in attaining these results. In any case, those once formidable conditions favorable to mosquitoes which were provided by nature, are now largely in the category of "under control subject only to maintenance."

It has only been during the past decade that we in California have come fully to realize that "man made" conditions favoring the mosquitoes are considerably more of a task to overcome than are those furnished us by nature. Since 1945, irrigated agriculture, industries, and growing communities have kept our local mosquito control agencies more than occupied. In fact during this period we have seen the number of agencies almost double (now a total of 54); more than quadruple in area served by organized mosquito control (now over 30,000 square miles); and considerably more than quadruple in annual expenditures (approximately $3,600,000 this fiscal year).

This past decade has seen artificially created water conditions, expressed in both size and number, become increasingly more available to vector and pest mosquitoes alike. Accordingly, solutions to these problems have become equally complex. Today we find mosquitoes being reared by the billions out of the same water being applied by the millions of acre feet to the very lands which are being developed and used to produce our wealth. The problem is being further accentuated by the liquid wastes coming from our industries and our communities. It is becoming ever more apparent that an increasing application of technical knowledge in the fields of agriculture, industry, conservation, and community planning is important to mosquito control workers in helping them to accomplish their complex tasks.

Within this changing picture of mosquito problems in California it regrettably appears that *Culex tarsalis,* the important vector of Western and St. Louis encephalitis, is becoming even more solidly established. Its wide range of habitat throughout the state and its adaptability to the various watered areas resulting from the artificial changes underway almost everywhere suggests potentially greater encephalitis incidence for future years. Such a trend calls for extraordinary effort by California mosquito control agencies in emphasizing abatement of the sources of this mosquito.

In addition to technical problems there are also administrative problems to be met, particularly as related to state-local relationships. As most of you in California are well aware, our State Health Department is solidly in support of local responsibility and maximum local autonomy in mosquito control. In the past several years considerable mutual understanding has developed between our staff and local mosquito control agencies, and there have been several concrete developments beneficial to mosquito control. Our Department's Vector Control Advisory Committee and the California Mosquito Control Association have rendered invaluable assistance to us in analyzing needs and helping to develop plans for going forward in state-local relationships on a sound and firm basis. We concur in our viewpoints with respect to the need for a strengthened program in mosquito measurement, operational investigations, and continued state subvention. California mosquito control is assured of the interest and support of this Department toward obtaining these objectives.

In glimpsing at the Conference program, several items have captured my personal interest, and I shall close with brief mention of these.

In looking over the program for this Conference, I am most impressed at the variety and latitude of the subjects to be discussed. I indeed regret that other commitments make it impossible for me to be with you throughout the Conference.

Approximately two years ago I had the opportunity to visit India and see the tremendous significance which mosquitoes bear to the health of the people and the economic development of that fascinating country. I should particularly like to hear Mr. Knipe and Mr. Johnson relate what is happening in India.

I should also very much like to listen to Mr. Henderson's paper on "Trends Apparent in Vector Control." As a pioneering state in this field we are most interested in getting new ideas and viewpoints and in testing our approach against the experiences of others.

The significant strides which our friendly rival state of Florida has made within its mosquito abatement program, I wish to acknowledge and commend. The farsightedness which is evident through provision of continuing funds for research on mosquitoes within the program administered by the Florida State Board of Health, and the direct emphasis on abatement type mosquito control measures as a state subsidy requirement, are both deserving of recognition and praise. I shall be listening carefully later on this morning when Mr. Mulrennan reveals his exclusive secrets as to how these fine developments were brought into being.

In conclusion, in keeping with the theme of the Conference, it is my privilege and distinct pleasure to publicly express the gratitude of our Board of Health and the entire Department to Harold Farnsworth Gray for his exceptional service to mosquito control and the many other aspects of public health upon which his advice these many years has been sought and so willingly given. Harold Gray, this honor to you is justly deserved and warmly endorsed. May your retirement be a rich experience, filled to the brim with activities which have been postposed for just this occasion.

I hope this will be an enjoyable and profitable Conference for all of you.

Mr. Grant: Thank you, Dr. Merrill, for the excellent paper giving the scope of work and the relationships pertaining thereto. I will call at this time on Charles Senn, Engineering Director, Division of Sanitation, Los Angeles City Health Department.

Mr. Senn: Mr. Chairman, and members of the conference. I have the honor of expressing the welcome and the symbolic key to the city for our Mayor Norris Poulson, who because of other commitments, couldn't be here to do these honors himself. I would like also to say that Dr. Uhl, our City Health Officer, extends his wishes for a successful and informative conference.

It certainly is fine to be here when we realize that this conference is dedicated to our good friend, Harold Gray, and we certainly would like to express our appreciation for the way in which you are doing him honor.

I could make mention of a number of aspects of mosquito control, but I think I would like to confine my few remarks here today not to the disease aspects, which we all realize are so important, but to some of the pest control aspects of mosquito control.

If you have read the newspapers here recently, you have read about our controversial statue on the new police building. It is called the "Faceless Statue." The man who is perhaps the most leading critic of this modern art is councilman Harold Harvey. He is a very energetic man who devotes 24 hours a day to the business of keeping his constituents happy. Some years ago Councilman Harvey called me, after midnight, and said, "Senn, they are getting me up all night; I might as well get you up. How about coming right out here by Loyola University." So I went out there and found the source of his trouble was a pretty heavy invasion of mosquitoes. By morning I had found myself overlooking the Hughes Aircraft Plant. In looking over this area, I saw a few ponds down there that might have been the source of the mosquitoes. I went to the gate; they asked who I was, and what I wanted. "Oh,—you will have to wait for the Captain of the Guard who will arrive at about 9:00 in the morning." (I was there about 5 o'clock in the morning).

So finally he said, "What are you here for?", and I said "Mosquitoes." He said, "Oh, those dive bombers, come right in."

They were working on a very secret project, but they dropped all efforts to keep me from seeing the plant when they took me in to show me around. They not only showed me what I wanted to see, but almost their inner secrets.

These ponds were rather small and I suggested, there being no DDT, the application of a little oil. Soon they were putting a 50 gallon drum of oil on each pond. I then suggested that maybe the ponds could be eliminated entirely. By afternoon they had gotten bulldozers in from some place and were eliminating these ponds.

I thought this little story illustrated two things: (1) that mosquitoes, as pests, are important. They were actually interfering with production in this plant, and (2) we don't always have to do the entire job for people. If we tell them what to do, they often are more than anxious to do it themselves. I think that is one of the lessons we carry from our public health sanitation programs into our mosquito control programs.

I think there is no phase of our work more gratifying than doing things for others, or preferably showing others how they can do things for themselves.

I wonder if there is anybody who isn't bothered by being bitten by mosquitoes? I wondered some years ago when I was working for the United States Indian Service laying out some highways up in northern Wisconsin. It was one of those muggy, damp, humid summers, when it was almost impossible to do a job of note, in keeping on looking through an instrument without having a smudge pot nearby; smoking so much you could hardly see your sights through the smoke, and the crew was entirely an Indian crew. Periodically, our lines in this virgin forest would cross a highway. Tourists would see the Indians, and every little while a tourist would say, "Well, I suppose you Indians can stay out here in the mosquitoes because we understand that mosquitoes don't bite Indians." The Indians would solemny say, "Yes, you are right." As soon as the tourist left, they would start laughing and slapping themselves on their legs saying, "What made these crazy tourists think mosquitoes didn't bite Indians."

Well, we hope that your visit here is not only enlightening, but also entertaining. We know that some of you who haven't been here before would like to see some Smog. We hope you won't see it while you are here. We don't like the stuff.

We wish we could arrange for each and everyone of you to see Marilyn Monroe on location but they are getting a little bit tough about letting people into the studios to see the shooting. But we do know that with the excellent committee you have here, the fine arrangements that have been made, and the excellent program here, that your stay in Los Angeles should be most enjoyable and profitable.

THE DEVELOPMENT OF MOSQUITO CONTROL PROGRAMS IN THE STATE OF OREGON

Milton H. Buehler, *Director*
Lane County Mosquito Control Program,
Eugene, Oregon

Mosquitoes have been recognized as an annoying problem throughout the river valleys and in the high mountain areas of the State of Oregon since the time of our earliest settlers. The most serious problems developed along the lower Columbia River Valley during the months of May and June when the Columbia River was at flood stage. As early as 1924 studies were made to determine if anything could be done to alleviate this serious mosquito nuisance; however, it was not until 1934 that control measures of any significant proportions were taken. In 1934 an allotment of Civil Works Administration funds was used to start a mosquito abatement program in the Portland area. This program has been continued with local and county funds, and is in operation at the present time. For years, the remaining portion of the state remained more or less oblivious to the presence of mosquitoes in spite of the fact that malaria was quite common in the upper Willamette Valley during the early days and continued to be of Public Health significance until as late as 1942.

Generally speaking, the mosquito problems in the State of Oregon can be divided into five main groups:

1. FLOOD WATER MOSQUITOES—*Aedes vexans* and *Aedes sticticus* are most numerous and annoying in areas adjacent to lands inundated by flood waters of the lower Columbia and Willamette rivers.
2. SALT MARSH MOSQUITOES—*Aedes dorsalis* is most annoying along the coastal regions of the state, particularly in areas adjacent to lowlands covered by high tides and at the mouths of coastal streams and rivers.
3. LOG POND MOSQUITOES—In the central valley area between the Cascade and Coast Range mountains, *Culex tarsalis, Culex pipiens, Culex stigmatosoma,* and *Culiseta incidens* are the most common species found in log ponds.
4. IRRIGATION MOSQUITOES — *Aedes dorsalis* and *Culex tarsalis* are the most abundant species found in the irrigated regions of central and eastern Oregon.
5. SNOWWATER MOSQUITOES—Various species of *Aedes* are found throughout the higher mountain areas of the State. Some of them are vicious biters and create a serious mosquito problem in heavily used recreation areas.

Following World War II several significant developments occurred with respect to mosquito control in the State of Oregon. *First,* there has been an increase in the mosquito population due to: (a) the construction of many small log ponds varying in size from one-tenth acre to one hundred acres, (b) there has been an increase in the number of acres of agricultural lands placed under irrigation and in the construction of low dams for the storage of irrigation water for farm use, (c) drainage problems have been created by the rapid development of suburban areas on lands having a high water table. *Second,* the population of Oregon has increased approximately 40% during this period. Many of the immigrants to Oregon have come from areas having mosquito control and have consequently voiced an opinion on the importance of mosquitoes and their control. Others observed mosquito and fly control measures while in the armed services and could see no good reason for not having some control of these annoying pests at home. As populations increased in many areas, a demand for more public services grew, one of which was an insect abatement program. *Third,* there has been a change in the thinking of many public health workers in the State of Oregon with respect to mosquitoes and mosquito control. Some public health workers became concerned with the possibility of having outbreaks of malaria. *Anopheles freeborni,* a vector of malaria, is present in great numbers in certain sections of the state. Although there have been few active cases of malaria reported in the State during the past ten years, past experience has shown that all of the factors necessary for malaria and its growth are present. The human carriers or reservoirs for the disease are present in returning veterans and in recent immigrants from malaria areas. Therefore, as long as the *Anopheles* mosquito is present, the malaria potential remains. The fact that encephalitis has reached epidemic proportions in our neighboring state of California within the past few years has caused considerable alarm among public health workers in areas where *Culex tarsalis,* the mosquito vector of the disease, is commonly found. This was particularly true in areas which have an increased number of log ponds close to population centers, the reason being that *Culex tarsalis* breeds profusely in log ponds. In addition, most public health workers now believe that freedom from disease is no longer enough and that the citizens of the communities should also be free of physical discomforts and annoyances. Thus, all mosquitoes, whether a vector or non-vector of disease, that bite man are now classified as being of public health significance.

As a result of this increased interest in mosquitoes and the need for mosquito control, several mosquito control programs have been started in various sections of the State. In 1948 Clackamas County contracted with the City of Portland for mosquito control services and a small program was also started in the vicinity of The Dalles. In 1950 a program was started in Umatilla County. In 1954 a cooperative program between the lumber mill operators and the County Health Department was started in Douglas County; at the same time three cities in Linn County started city mosquito control programs. During 1953 mosquito control programs were started in Lane, Coos, Columbia, and Harney Counties. During the past season, 1954, a program was started in Marion County and an unsuccessful attempt was made to start a program in Jackson County.

Each of the above programs vary in size, scope, efficiency, and effectiveness, dependent upon the mosquito problems involved, availability of funds, number and degree of trained personnel, as well as community acceptance of the individual program. A brief description of several of these programs can best describe the overall development of mosquito control programs in the State of Oregon.

CITY OF PORTLAND. The City of Portland has the oldest and largest mosquito abatement program in the State. It provides mosquito control for the City of Portland, Multnomah County, Clackamas County, and several counties across the Columbia River in the State of Washington. All services to areas outside the City of Portland are done on an annual contractual basis. The greatest source of mosquito nuisance comes from the flooded areas along the Columbia and Willamette Rivers during flood state in May and June. However, irrigated fields, fresh water sloughs, ponds and streams, roadside ditches, and artificial containers are also very important mosquito sources. In the past, most of the control activities were confined to aerial spraying and fogging; however, during the past season better results were obtained by increasing ground activities in both larval and adult control. The program is under the administration of the Portland Health Department, has a full time trained director, and is tax supported. The 1954 budget, including fees for contracted services, was $64,000.00.

LANE COUNTY. Lane County established a countywide mosquito control program in 1953. The mosquito control problems of the Lane County are quite typical of those found in most sections of the State. Log ponds varying in size from one-tenth acre to seventy acres are the greatest single source of mosquitoes. Lane County has over ninety such ponds with a total area of more than 530 acres. Unlike other bodies of water of similar size, the log pond produces mosquito larvae over the entire area of the pond, regardless of the depth of the pond and absence of protective vegetation. The suspended and dissolved organic matter in the ponds seems to create an ideal media in which to rear mosquitoes. As many as 400 larvae per dip have been collected from log ponds, 100 per dip are quite common. Due to the location of the ponds with respect to sawmills, loading docks, and other plant facilities, access to the ponds is often limited to one side or to one end. It was therefore necessary in Lane County to design special spraying equipment capable of treating all ponds, regardless of size, from one side. The common practice of cold decking or stacking logs in the center of the ponds in one or more tiers to heights of fifty or sixty feet further complicates the problem of treating them. In addition to these log ponds, roadside ditches, sloughs, irrigated pasturelands, catch basins, faulty septic tanks, and other artificial containers are also responsible for a large mosquito population. Mosquito control activities in Lane County are divided into three components: larval control, adult control, and source reduction by drainage. All known mosquito sources are routinely sprayed for larval control. Adult control is provided by routinely fogging an area of approximately 136,000 acres every eight days with a fog machine. The fog machine was also built by Lane County. Adult control in high mountain recreation areas has been carried out on a limited scale due to the heavy use of these areas by local citizens as well as traveling visitors. The program is under the administraton of the Lane County Health Department, has a full time trained director, and is tax supported. Lane County spent a total of $22,500.00 on mosquito control during the 1954 season.

DOUGLAS COUNTY. The Douglas County program was started in 1951 as a cooperative program between the sawmill operators and the Douglas County Health Department. The mill operators furnished the money to buy larvicidal chemicals, and the health department borrowed some equipment and furnished the labor needed to apply the larvicide. The labor was furnished at no additional cost by merely increasing the duties of an already overworked staff of sanitarians. In spite of its meager beginning, the program has made considerable progress. Activities now include larval control, some adult control, and some source reduction. An additional sanitarian has now been employed to work full time on mosquito control during the main mosquito season; during the winter months he works on other health department activities. In addition, considerable ground equipment has been purchased. The program is under the administration of the Douglas County Health Department. The budget for 1954 was $5100.00; of which $1725.00 was assessed against the mill operators at the rate of $5.00 per log pond acre, $500.00 was contributed by the City of Roseburg, and the balance of $2875.00 was taken from the county general fund.

COOS COUNTY. During 1953 the Coos County Health Department added a mosquito control program to an existing rodent control program, thus creating a general vector control program. A full time sanitarian is employed to carry on vector control activities. Although present personnel were trained for rodent control, they have been able to get some good results in mosquito control. The program was allowed approximately $1200.00 for the purchase of equipment. The 1954 budget for vector control in Coos County was $4500.00. The program is tax supported, and is a functional part of the health department.

UMATILLA COUNTY. A mosquito control program was started in Umatilla County in about 1950 as a Health Department activity in an effort to control large populations of mosquitoes coming from irrigated pasture lands. Changes in personnel, poor program planning, inadequate financing, failure to develop community support, and lack of properly trained personnel all contributed to the inadequacy of the program. After several years of half-hearted attempts at larval control, the program was abandoned in 1953.

CITY PROGRAMS. Each year at the height of the mosquito season or immediately following newspaper accounts of mosquito borne disease epidemics, several small towns or cities start a mosquito control program. Most of these programs are financed by popular subscription; however, there are a few cities that budget annually for some mosquito control. In general the city type program consists of hiring a commercial crop-duster to spray the city and immediate environment with a DDT-oil soluton. One are two applications may be made during the height of the mosquito season, depending upon whether or not good results were obtained by the first treatment, and whether or not there is enough money left to spray the town again. The following table lists the city programs by County, giving the year the program was started, the amount of funds budgeted for 1954, and the effectiveness of the program.

City Mosquito Control Programs in the State of Oregon in 1954

County and City		Year started	1954 budget	Effect. of Program
BAKER	Baker	1954	$ 300.00	Fair
COLUMBIA	St. Helens	1953	500.00	Poor
CROOK	Prineville	1954	500.00	Good
HARVEY	Burns, Hines	1953	4,390.00	Poor
LINN	Albany	1951	2,000.00	Poor
	Lebanon	1951	500.00	Fair
	Sweethome	1951	500.00	Fair
MARION	Salem	1954	4,000.00	Poor
WASCO	The Dalles*	1948	500.00	Fair

* Some funds contributed by Wasco County.

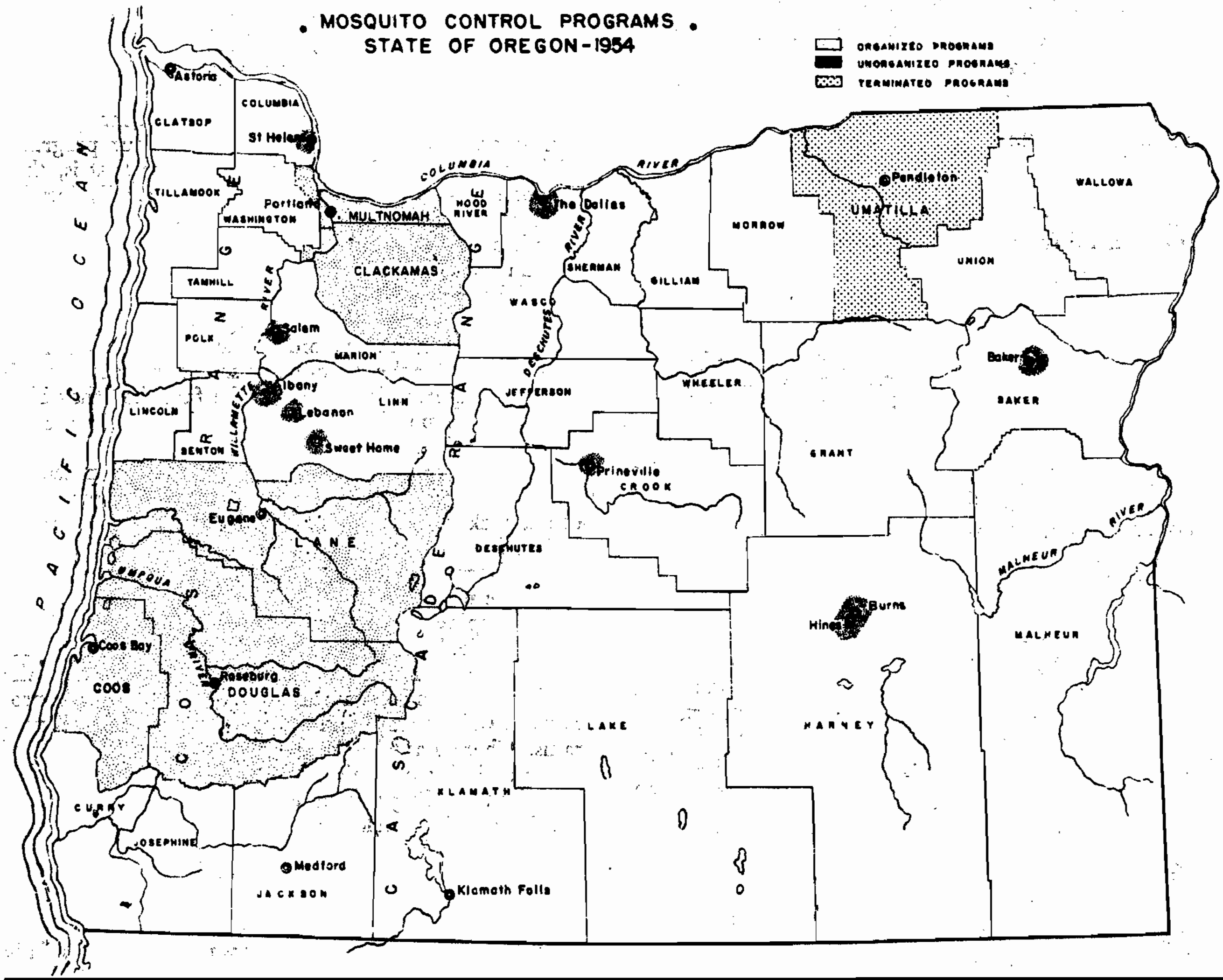
Thus it becomes apparent that programs in the State of Oregon can be classified into three groups. In the first group there are two programs that have sufficient funds and trained personnel to provide effective mosquito control efficiently and economically, in large densely populated areas. There are perhaps three or four programs which can be placed in the second group; that is, they have personnel with some training but usually insufficient funds to provide good mosquito control. They, never-the-less, still provide a pretty good mosquito control program in limited areas, or partial control in larger areas. The remaining programs fall in a third group which, in most cases, is unsatisfactory. These programs are unorganized, un-economical, and ineffective. They are usually under the direction of someone whose knowledge of mosquitoes is limited to the fact that they bite; they are often poorly financed; and funds that are expended are often spent unwisely.

One of the greatest handicaps in the development of mosquito control programs in the State of Oregon has been a lack of trained personnel. The State Board of Health, due to lack of funds, has not yet been able to provide advisory assistance for local programs. Trained personnel are not yet available to advise and train City or County employees in modern mosquito control methods. State laws dealing with vector control and vector control programs leave much to be desired with respect to the establishment and organization of vector control programs as well as ways and means of financing such programs. There has also been reluctance on the part of county and city officials to support vector control programs by providing adequate funds, insisting upon qualified personnel, or delegating administrative authority to one person or one agency.

Many of those engaged in mosquito control work feel that the future of vector control in the State of Oregon is bright. There are several good mosquito control programs under way which are being watched very carefully and with considerable interest by people living in areas not having mosquito control. As the programs have developed throughout the state, gradually more and more people have been getting actual field experience in mosquito control. We are in the process of setting up a state-wide mosquito control association to facilitate the exchange of ideas and techniques among those employed in mosquito control. Our first meeting was held in Portland on December 15, 1954. There were over 20 people engaged in mosquito control who attended and contributed to this meeting. Actually we are just getting started in the field of mosquito control in the State of Oregon. We have a long way to go, but we are making progress.

Summary

Mosquito control was first started in the State of Oregon in 1934; however, few mosquito control programs received general public support until about 1951. The greatest handicaps in the development of mosquito control programs have been (1) lack of trained personnel, (2) inadequate state laws dealing with vector control and vector control programs, (3) reluctance on the part of local governmental officials to support vector control programs, provide adequate funds for such programs, or to insist upon having qualified personnel in charge of such programs. In spite of the above handicaps, considerable progress has been made during the past few years in the field of mosquito control. Since 1951 there has been an increased interest in mosquito control in many sections of the state. In 1954 there were five active county programs



and ten city programs having total budgets in excess of $106,790.00. All of the major mosquito control programs and a few of the city programs are under the administrative jurisdiction of local county or city health departments. Two mosquito control programs in the state have full-time directors; the balance have little or no organized or technical direction. Many of those engaged in mosquito control work feel that the future of vector control in the State of Oregon is bright. A state-wide mosquito control association is being formed to facilitate the exchange of ideas and technical information. The first state-wide meeting was held in December, 1954; twenty people engaged in mosquito control were in attendance. We in the State of Oregon are relatively new in the field of mosquito control; w have a long way to go; however, progress is being made.

Dr. Rees: Mr. President, Ladies and Gentlemen: First, I would like to extend greetings and best wishes to all of you from the mosquito abatement workers of the Rocky Mountain Region and especially to Harold Gray for the work that he has done in mosquito control, and the assistance that he has given us. He is well known by the numerous trips that he has taken into our region and we appreciate the excellent work he has done.

Secondly, I would like to extend to all of you an invitation to attend the Utah Mosquito Abatement Association meeting which will be held on March 18 and 19 at Farmington, Utah. Farmington is just a few miles outside of Salt Lake City. You will find accommodations in Salt Lake City and we will provide transportation to and from the meetings.

RECENT ADVANCES IN MOSQUITO CONTROL IN THE ROCKY MOUNTAIN REGION

by

Don M. Rees, *Regional Director*
Salt Lake City, Utah

The Rocky Mountain Region of the American Mosquito Control Association, Inc., now includes the following nine states: Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, South Dakota, Utah, and Wyoming. In an attempt to determine the extent of mosquito abatement operations in these states during the past year questionnaires were mailed to the principal health officers and other individuals known to be interested in mosquito control work in each of these states. The response to these questionnaires was prompt and practically all of them were completed and returned.

An outstanding conclusion that can be drawn from the information contained in these questionnaires is that in

MOSQUITO ABATEMENT OPERATIONS OF A.M.C.A. IN THE ROCKY MOUNTAIN REGION
1954

State	*State Enabling Legislation*	*Passed*	*Organized Districts*	*County Control Agencies*	*City or Local Control Organizations*	*Expended Estimate 1954*
Colorado	no			none	5+	$ 2,500.00
Kansas	no			?	?	25,000.00
Montana	yes	1953	none	2	8	4,000.00
Nebraska	no			none	5+	4,000.00
New Mexico	no			1	none	2,500.00
North Dakota	no			none	5+	25,000.00
South Dakota	no			none	14	4,000.00
Utah	yes	1923	6	none	7	200,000.00
Wyoming	no			none	8+	2,500.00
					Total	$269,500.00

some of the states, such as Colorado, there are considerable differences in opinions concerning the extent of mosquito abatement operations in the state and the amount of money expended for this purpose. In other states it was surprising to learn how extensive mosquito abatement operations are, although no enabling legislation has been passed in the state to provide for the organization and operation of mosquito abatement districts.

In preparing the information contained in this report, I have recorded the results obtained from these questionnaires. Where there have been differences in the replies from individuals in the same state an attempt has been made to select the information which seems to be more fully substantiated by the data presented.

In considering the data contained in the above table, it should be remembered that while the Rocky Mountain Region is perhaps geographically the largest it probably is least in population per acre as compared to the other regions in the United States. It is obvious that there is a great need for the development of mosquito abatement operations in most of the states in this region, as Utah spent in 1954 almost three times as much for mosquito abatement as the other eight states combined. Utah's mosquito control problems are certainly not that much greater than the other states in the region.

It is encouraging to note that all of the states in the region did some abatement work in 1954, and I am confident this work will be extended in 1955. This will be the case especially where the results have been most effective because of the employment of trained personnel.

An outstanding contribution to mosquito abatement work in the Rocky Mountain Region is the research being conducted in Utah by the Logan Field Station Section, Technology Branch, C.D.C. of the Public Health Service. This Field Station, now under the direction of Dr. Archie D. Hess, was established in January, 1954. According to information obtained from Leslie D. Beadle, "is concerned with three main types of research activities, viz. (1) studies on arthropods of public health importance associated with water utilization; (2) arthropod-borne encephaltis studies; and (3) plague investigations.

"During 1954 research and investigations on mosquitoes and encephalitis were carried on in the following localities of the Rocky Mountain Region: Logan and Weber Basin, Utah; Hot Springs, South Dakota; and Chinook, Montana (related activities are being conducted at Field Stations in Texas and California).

"In the Logan area, emphasis was given to bionomical studies on mosquitoes, especially *Culex tarsalis*. These included population studies, biting studies, seasonal activity of *C. tarsalis*, and development of improved sampling techniques for mosquitoes.

"During the summer 47 shipments of over 16,000 mosquitoes, chiefly *C. tarsalis*, were sent to the Rocky Mountain Laboratory, NIH, Hamilton, Montana, for encephalitis virus recovery tests. The specimens were collected from various irrigated areas in Utah, Montana, and Idaho.

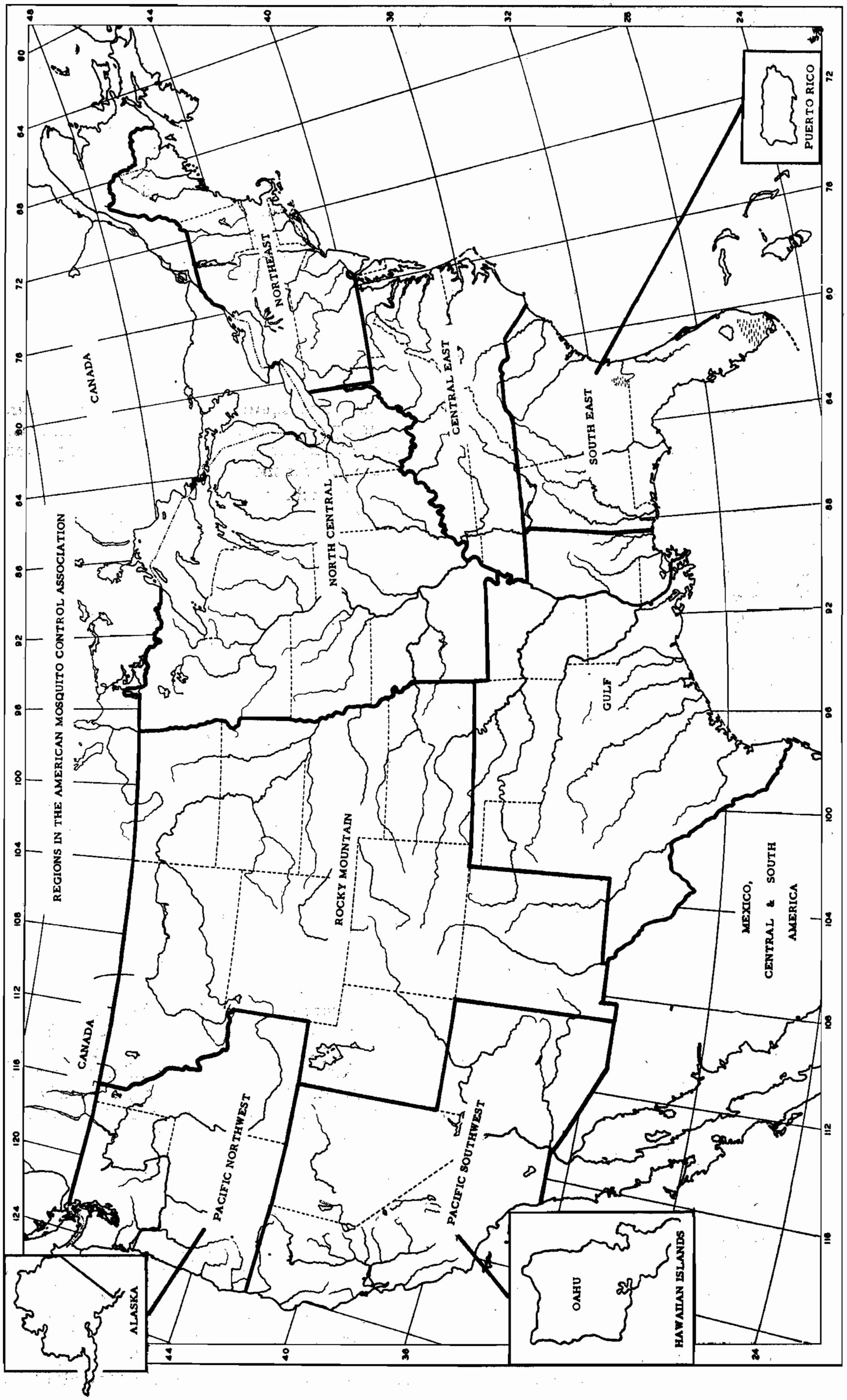
"Entomological-engineering studies were carried out at the Milk River Irrigation project in Montana, the Angostura Irrigation project in South Dakota, and the Weber Basin project in Utah. The objectives of these investigations are (1) to develop practicable measures for prevention and control of mosquito problems associated with irrigation, and (2) to develop cooperative working relationships with Federal, State, and local agencies for solving vector problems associated with new and established projects.

"Another type of activity carried on by the Logan station involves a critical review of project reports by Federal agencies to integrate vector control with other interests on multipurpose water utilization projects. During the year reports on ten projects located within the Rocky Mountain Region were reviewed and vector control recommendations submitted to U. S. Army Corps of Engineers, U. S. Bureau of Reclamation, and U. S. Fish and Wildlife Service."

The work in progress and the cooperation and assistances received from the personnel at this field station are greatly appreciated in the Rocky Mountain Region. They are making an outstanding contribution to mosquito control operations in basic research, especially as related to water utilization, which is the most important mosquito control problem of states where irrigation is practiced.

As members of A. M. C. A. we hope to more fully enlist the continued services of this corp of workers at the Logan Field Station to develop more extensive and effective mosquito control activities in all states in the Rocky Mountain Region.

President Dorer of A. M. C. A. set a quota for the regions to shoot at during 1954. For the Rocky Mountain Region he asked for 5 new members; we have obtained over twice the number. As requested by President Dorer, we have encouraged the promotion and the organization of mosquito abatement work in the region. An operational article is now being prepared for Mosquito News and we



REGIONS IN THE AMERICAN MOSQUITO CONTROL ASSOCIATION are trying to obtain a new advertising account.

We are pleased with the progress we have made during the past year and are looking forward to a better year in 1955.

POLITICAL AND SOCIAL ASPECTS OF INSECT CONTROL

OTTO MCFEELEY, *President*
Board of Trustees, Des Plaines Valley Mosquito Abatement District, Lyons, Illinois

Being aged and garrulous, I will take time to reminisce. This will be done with restraint. Only to illustrate a few points.

In 1887 when I was 12 years old, I was compelled to commit to memory and to speak the speech Spartacus was supposed to have spoken to start the slave revolt in the first century B. C.

The slave gladiator spoke:

"Ye call me chief and ye do well to call him chief who for twelve long years has met in the arena every shape of man or beast the broad Empire of Rome could furnish. Rome has been a tender nurse to me. She has taught me to drive the tempered steel through links of rugged brass and to look into the eyes of the fierce Nubian lion as a boy upon a laughing girl."

So after all the years I have been a member of this learned society I have been asked to speak.

Not as a chief, but as the most tortured and scarred survivor in this organization in the never-ending war between man and insects.

In my childhood we lived in a more intimate manner with insects than civilized Americans of today.

The result was typhoid fever, the shakes, ague, and widespread debility. I had typhoid, the ague, and so did my brother and sister, and my mother.

The prevailing opinion then was that we were "afflicted of God." All the family, except my father, went to our devotions regularly. But my father, who lived to be 86, never in his life had any contagious or infectious disease. This perplexed the little boy I was then. Why should father, the unfaithful and unbeliever, escape the affiction of God, when the devout so often suffered?

Now in that community there is no ague, no shakes, no typhoid. Rational science worked the cure. Every one there now, including doctors of divinity, knows that the diseases were the work of the fly and the mosquito, and that typhoid results when one ingests human excrement.

In 1896 I went to Guatemala with a surveying party, and to achieve malaria. I escaped in skin and bone, and it seems to me that the disease handicapped me for years.

It came to pass then I went to live in Oak Park, Illinois, and nearly twenty-five years after the Central American plague there was another mosquito plague, due to pollution of streams. They were really open sewers.

My three year old daughter was vulnerable and suffered greatly. I really was energized and began a campaign to do something about it.

Mass meetings were held to denounce the insect.

Thousands of dollars invested in decorations were lost when blood fed insects were swatted on the walls.

I proposed that vacuum cleaners be used and that was a great invention.

One powerful politician of the County started to wipe out the mosquitoes. Hundreds of unemployed men in trucks advanced on the streams with barrels of oil; the politician's name painted on each barrel. I believe he spent $500,000 without any effect whatever.

Years passed. We suffered. I employed entomologists to make a survey. But nothing happened until 1927 when the state legislature adopted a law authorizing formation of abatement districts. Ours was among the first and, until last year, the only one on the west side or south side of Chicago.

The late Dr. Fuller, well known to many present, was largely responsible for the new law.

Fortunately we engaged J. Lyell Clarke who for 25 years was our engineer. Fortunately for the district we had a depression and the WPA.

Under the aggressive leadership of Mr. Clarke we had the free services of unemployed engineers. At times we had a thousand WPA laborers. They excavated about a thousand miles of ditches, mostly laterals. That went on for eight years.

Six hundred miles of the drains are in the district; the remainder outside, designed to protect our flanks.

Upon organization of the district in 1927 I was appointed a trustee, one of five, and have served ever since, without pay, as the law requires trustees to serve as honorary officials.

Including cost to the federal government for WPA workers, and money we have collected in taxes, we have spent more than four million dollars in twenty-seven years.

Oak Park, largest of 26 incorporated towns and villages, with 63,000 souls, has paid an average of $22,000 annually, the total for 27 years being greater than a half million dollars.

All this seems expensive for what really is a luxury, as the insects at present are no serious menace to health, although they have been suspected of being vectors of polio.

It is a luxury for 234,000 people. The cost last year was 42 cents per capita.

Of each one hundred dollars paid in real estate and personal property taxes, our district received 52 cents. That is about the cost of two packages of cigarettes, and less than the cost of one cocktail.

We have no more than an occasional annoyance from insects coming into the district. Last year our Mr. Wray and his entomologists had to go out of the district to get larvae for laboratory purposes.

We have never been harshly criticized. Years have passed without any criticism at all.

Last summer we received 80 mild complaints. Some were chronic complainers and others complained of honey bees that were stinging children.

Our escape is due to the fact that our tax is so minute in the total tax system, and also we have the most politically immature people in America.

I estimate that not one citizen in 500 is aware that we live on taxes. They consider our work as a sort of Red Cross or Boy Scout project.

Only 14 votes were cast in Oak Park, with a population of 63,000, in the referendum to set up the district and levy taxes, now amounting to more than a half million in 27 years.

The cost will be less this year. Finally our southern flank is to be protected by a larger district. Dr. Czarnetsky, President of the new district, and Col. Buchanan, well known to you, who is to direct the work, are present here.

The new board is composed of citizens biased in favor of honorable conduct and committed to the scientific approach to their duty.

How long it has taken to accomplish what we have in this country, health, longevity, and the most humane society in history, extent and population considered.

It is a bit humiliating to realize that we owe more to Italian, French, and English scientists for scientific mosquito control than to our own people. The mosquito was suspected by Italian scholars as early as 1804.

But in 1828, Fenimore Cooper, writing of yellow fever in New York City, reported that physicians were baffled. The disease spread without any evidence of contagion or ordinary infection. They finally decided the fever was caused by miasmata. They were correct in one respect. It did come from the air, via flying insects, but no one suspected the mosquito.

It should be observed at this moment that our supremacy in atomic and hydrogen weapons is due more to Italian and German scientists than to our own.

At present governmental agencies are hounding scientists and preventing exchange of theories and ideas with foreign scholars. That way lies disaster and I do hope those present will take every opportunity to halt such measures designed by our native lunatic fringe.

I am greatly indebted to the New Jersey Association and to this society for an education that has aided me in the discharge of my public duties. I urge all trustees, commissioners, or other officials elected or appointed to such duties to attend these sessions. If they do not, they will neglect their public responsibilities.

We have more than 600 miles of ditches. We cannot clean them with hand labor. We know of no machine suitable for the purpose, and there is no WPA. So we are attempting to design a machine to clean our small laterals.

Mr. Charles F. Scheel, on our board for 23 years, has accepted the duty of experimenting and study of the cleaning problem. If any one present today has any ideas or suggestions, I urge them to seek out Mr. Scheel at once.

MOSQUITO CONTROL IN TEXAS

R. B. Eads[1] Frank J. Von Zuben, Jr.[2]
George A. Thompson[3]

The mosquito fauna in Texas shows a wide range of generic and specific variation as a result of the diverse ecological conditions provided by the rain forests of East Texas and arid western half of the State, and the near-tropical Lower Rio Grande Valley. The State Department of Health bulletin "Mosquitoes of Texas" which has been recently revised lists 71 species, exclusive of sub-species, as being present in the State. Several of them are limited in their United States distribution to the Lower Rio Grande Valley.

Historically, mosquito control in Texas has been applied principally in East Texas and the Lower Rio Grande Valley as antimalarial measures. The salt marsh mosquito problem along the Gulf Coast has evoked the fatalistic attitude of "what must be, must be." However, within the last ten years conditions have been changing rapidly. The decline in malarial incidence to the point of virtual disappearance has lessened interest in mosquito control at the municipal level in East Texas. There is now considerable enthusiasm along the Gulf Coast relative to the possibility of controlling our salt marsh mosquitoes since the Jefferson County Mosquito Control District has demonstrated the excellent results which can be obtained by a well organized and efficiently operated county program.

There has recently been a marked increase in interest in mosquito control in West Texas, as a result of increased mosquito annoyance and the occurrence of a considerable number of cases of encephalitis in both man and horses. The increased incidence of the arthropod-borne encephalitis may be due in part to improved diagnostic acumen of the medical profession in the differentiation of the neurotropic virus diseases, but it undoubtedly has been affected by the tremendous population increase and the spectacular expansion of irrigation agriculture. Certain counties in the Southern High Plains of Texas have reported better than 100 per cent population increases since 1940; over three million acres are under irrigation in the area, with the water being obtained largely from deep wells.

The Texas State Department of Health and the Logan Field Station, Communicable Disease Center, Public Health Service, instituted cooperative encephalitis studies in the Lubbock-Plainview area subsequent to an outbreak of the disease in horses and human beings during the summer of 1952. Several human cases of western equine encephalitis received laboratory confirmation during 1953 in West Texas. During the summer of 1954, serological evidence of the occurrence of both western equine encephalitis and St. Louis encephalitis has been obtained in West Texas.

The encaphalitis studies revealed that extensive breeding of *Culex tarsalis* mosquitoes occurs in playa lakes, roadside ditches and borrow pits in that section of the State. Further cooperative studies will consist in the physcal modification of the playas, water level management, improved irrigation practices, and preflood, as well as post flood larviciding to determine the most effective approach to curtailing the propagation of the vector.

In late August, 1954, there was an epidemic of encephalitis in Hidalgo County during which over 500 people were stricken. Serological tests and recovery of the virus from a human brain and pools of *Culex quinquefasciatus* mosquitoes indicated that St. Louis virus was probably the etiological agent responsible for the outbreak.

Wth the able assistance of the Epidemic and Disaster Aid Section of the Communicable Disease Center, Public Health Service, an emergency control program was promptly organized and effectively placed in operation on a county-wide basis. Both adulticiding and larviciding procedures were followed. A sharp decline in the incidence of the disease was observed following the reduction in the adult mosquito population.

An important facet of the encephalitis problem is the widespread utilization in Texas of oxidation ponds for secondary sewage treatment. Almost 200 cities and towns utilize this method since it is economical, effective, and allows the effluent to be conserved for irrigation purposes.

Although economical in construction costs, the ponds are usually constructed of earthen levees and are subject to emergent vegetation hanging into the water at the intersection of the levee and the water line. This condition

1 R. B. Eads, Principal Entomologist, Bureau of Laboratories, Texas State Department of Health.
2 Frank J. Von Zuben, Jr., Senior Engineer, Bureau of Sanitary Engineering, Texas State Department of Health.
3 George A. Thompson, Director, Jefferson County Mosquito Commission.

provides mosquito larvae ideal shelter and is responsible for conditions that are conducive to the development of *Culex tarsalis.* It is fairly simple to eliminate the various types of aquatic vegetation in the body of the pond through good initial design practices. An extensive survey of oxidation ponds is currently underway in the State, and most of the ponds have been found to be breeding *Culex tarsalis,* as well as other species of mosquitoes. This poses a somewhat difficult problem, since vegetation is needed to stabilize the earthen banks, and proper maintenance involving physical labor is difficult to obtain. Consideration is being given to developing several types of investigative projects which will include the use of herbicides and possible physical modificaton of the banks to both stabilize the soil and prevent the occurrence of vegetation at the water line.

Restricted mosquito abatement legislation was first enacted in Texas by the state legislature March 15, 1949. It provides for the Commissioners Court in all counties of the State which border on the Gulf of Mexico to call an election to determine if the qualified voters of such county desire the establishment of a mosquito control district to embrace all the territory within the county. The law further provides that the County Judge must be petitioned by a minimum of 200 qualified voters in the county before the election can be scheduled.

The legislation provides for the Commissioners Court in each county in which a Mosquito Control District is created to appoint an Advisory Commission composed of 5 members who shall be qualified property tax paying voters of the county. Each commissioner of the Commissioners Court and the County Judge appoints one member of the Advisory Commission. Members of the commission serve without compensation. The chief duties of the Advisory Commission are to make recommendations to the Commissioners Court as it deems necessary to carry out the provisions of the act, and as may be needed for the successful operation of the abatement program. The Commissioners Court is authorized to appoint a mosquito control engineer, or other well qualified specialist to direct the operational activities. The engineer is directly responsible to the Commissioners Court for conducting the program.

The legislation provides for the Commissioners Court to levy a tax not to exceed five cents on each one hundred dollar tax valuation to finance the abatement program. The taxes are collected by the County Tax Assessor and Collector and are deposited in a separate fund to be used for the purposes of carrying out the provisions of this act and for no other purpose.

Since the enactment of this legislation in 1949, four Gulf Coast Counties have voted favorably on the establishment of Mosquito Abatement Districts. They are Jefferson, Galveston, Chambers, and Aransas Counties. Jefferson County has had an active operation program since 1949, while Galveston County has only recently voted favorably on establishing a district. Both Aransas and Chambers Counties voted favorably on the establishment of abatement districts shortly after the legislation was enacted; however, since the tax evaluation is low in these counties, there are insufficient finances to operate effective programs. Aransas County has purchased an airplane and occasionally hires a pilot to treat the areas surrounding the population concentration centers when annoyance from *Aedes sollicitans* becomes too severe.

Keen interest in controlling mosquitoes continues to be manifested by the general public, and it is anticipated that other currently eligible counties will establish control programs in the near future.

At the present time, the Texas State Department of Health is unable to supply direct monetary support to the mosquito abatement districts. However, state funds are being expended on abatement activities through the city and county health departments which derive financial support from the State Health Department. Mosquito control work in Texas currently is, for the most part, in the hands of municipal authorities. Most cities and towns operate some type of mosquito control program, confined almost entriely within their respective corporate limits.

The State of Texas is currently in need of more adequate enabling legislation to control mosquitoes and other insect vectors. Proposed revisions in the existing law that will be considered during the current session of the State Legislature will provide for the control of any arthropod of public health or significant nuisance value, make provisions for adequate financing, permit any county in the State to develop a county-mosquito control district, and many other desirable features. Since a constitution amendment will be required, it will take a minimum of two years before the new legislation will be available to the local governmental agencies.

State entomological and engineering specialists in mosquito control are available to assist eligible counties in organizing and operating control districts. The State Health Department maintains a Division of Vector Control, largely devoted to control activities and a Medical Entomology Division, occupied chiefly with research on arthropod-borne diseases.

MOSQUITO CONTROL IN OHIO — PROGRESS REPORT

Bruce Brockway, Jr., *Administrator*
Toledo Area Sanitary District, Toledo, Ohio

Before I left my office I received a telegram which read: "May you have as successful a visit as I had, and give my sincere regards to all the Californians," signed Woody Hays.

When Dick Peters asked me to give a progress report on mosquito control in the State of Ohio, I hesitated a long time, because the Toledo Area Sanitary District is the only governmental agency in the state interested in this type of work, and which uses virtually all types of control measures.

Numerous cities such as Cleveland, Dayton, and Columbus use fog machines for adulticiding operations when mosquitoes become an unbearable nuisance. My source of information tells me that most of these machines are owned and operated by private individuals, or by pest control companies. There are some smaller towns like Brian, where limited spraying programs are carried on under the guidance of the County Health Department; but these communities are few.

Interest in mosquito control in the State of Ohio is limited to the period when mosquitoes are biting. As an example, only six Ohio health department city and county officials attended our seminar last September, while about 85 invitations were sent out from our office. To this information, I might add, that during this same period, or from May to July, our office receives about a dozen calls each year from various small towns requesting mosquito control information. In some instances their calls are pleas for help needed right away.

The progress of control in Ohio is slow and, in most cases, is a problem of learning the hard way.

I would like to mention at this moment that the Proceedings for the Seminar have at last been printed. Any of you who did not attend the meetings (we are sorry that you didn't attend) will find this publication to be full of frank facts, as well as theories; and, if you will give me your card, I will see that you get a copy for $1.00. Thank you.

NEW ENGLAND

EDITOR'S NOTE: Bertram I. Gerry, Secretary of the Massachusetts State Reclamation Board, was originally scheduled to present a review of mosquito control activities in New England. However, in a letter to R. F. Peters, Program Chairman for the American Association, Mr. Gerry offered an excellent reason for his inability to attend this Conference, as is evidenced in the following quote from his letter:

"In reply to your invitation of 16th November to present a brief account of mosquito control developments in Massachusetts at the Joint Mosquito Control Association Conference being held in January 1955 at Berkeley, California—unfortunately a tangle, which occurred while attempting to establish a New England Mosquito Control Association, has eliminated all opportunity to absent myself from the State during January.

"Our early efforts to reach individuals, interested in the formation of a New England Mosquito Control Association, indicated the necessity for cooperation with some well known blanketing organization from which we might gain contacts. We solicited, therefore, assistance from the State Extension Service. As a result of our request, this Service scheduled an organization meeting for 3rd and 4th of February during conference week at the University of Massachusetts. As Chairman of the Constitution and By-Laws Committee, I feel compelled to make myself available just previous to and during the scheduled meeting."

Dr. Collins: Members of the two associations. I bring you greetings from Dr. Glasgow, former Editor of Mosquito News and a man whom you all know and respect for his early work in helping to organize the American Mosquito Control Association. Also, I bring you greetings from Chris Williamson and Leroy Kinsey whom most of you know for their mosquito control activities; some of which I will mention.

MOSQUITO CONTROL IN NEW YORK STATE IN 1954

D. L. COLLINS, *State Entomologist*
New York State Museum and Science Service

Considered as a state unit, New York occupies an anomalous position with respect to mosquito control activities. The state law governing the establishment of mosquito control commissions, by its unusual wording[1] effectively restricts the formation of mosquito control commissions as such to Suffolk County. However, under the general public health laws, county and town boards are permitted to control mosquitoes within their boundaries.

Under these laws, there were several different types of organized mosquito control activity in New York in 1954. In Suffolk County, which comprises the eastern half of Long Island, the work was done by the Suffolk County Mosquito Control Commission.

In Nassau County, a similar commission operated until 1947, but since 1947, the work has been performed by the Mosquito Control Division of the County Department of Public Works.

In upstate New York, the picture is entirely different. There are few if any counties where there is county-wide sentiment for organized mosquito control. Under these conditions mosquito control may be a function of a village, city, or township depending on the area of demand. Within the political subdivisions the funds may come from different departments such as public works, parks, or health.

It happens that a certain amount of mosquito control activity occurred in 1954 within each of the categories mentioned, so in order to keep each area of the picture clear they will be discussed separately under appropriate headings.

1. SUFFOLK COUNTY. This is the only county in the state with a Mosquito Control Commission organized on a basis similar to those operating in New Jersey, California, and a few other states. Chris Williamson is Director and Superintendent. He has reported personally on Suffolk County Mosquito Control activities as AMCA meetings in the past, so that AMCA members are familiar with the general features of operations in that county. He has kindly furnished me with the information which I am about to give on the activities in 1954.

As most of you know, Suffolk County occupies the eastern end of Long Island, New York, and is surrounded on three sides by salt water. The shoreline is deeply indented by numerous bays, large and small, and there are many low-lying salt marsh islands as well as extensive areas of salt marsh on the island proper.

In addition to the control of salt marsh mosquitoes, there are two principal problems which the Commission handles, namely, control of upland freshwater species and control of domestic species. The salt marsh species include *Aedes sollicitans, A. taeniorhynchus, A. cantator,* and *Culex salinarius. Anopheles crucians* has been encountered occasionally. The freshwater and domestic problem mosquitoes have been *Aedes vexans* and *Culex pipiens.*

In 1954 the areas described as "under control" in Suffolk County comprised 914 square miles. The total budget was $283,516.00. The number of men employed was 70. Materials used for chemical control (i.e., larviciding, including oiling) were as follows: 6 tons of technical DDT, 6,750 gallons of 25% DDT emulsion concentrate, 93,000 gallons of No. 2 fuel oil. Equipment used on the salt marshes included both hand and power sprayers, and for the ditching and other work, four Oliver OC-6 tractors and Scavel plows. The drainage systems are completely overhauled every two years. The larviciding solutions were mostly 2.2% DDT in fuel oil.

On th uplands, operations included drainage and spraying using 2.17% and 5% DDT solutions. Some residual applications with 5% DDT solutions were also made, with very good results.

A research program was carried on with the New York State Science Service on insects other than mosquitoes that are a community nuisance. This is a yearly program operated jointly by the Suffolk County Mosquito Control Commission and the New York Science

[1] Any county which is "adjacent to a county which contains more than three towns and which is adjacent to a city of the first class, having a population of over 3 million" can have a county Mosquito Extermination Commission.

Service, under the direction of the State Entomologist. In 1954 the work done under this arrangement included investigations of the nuisance gnats *(Tendipes decorus)*, salt marsh tabanids *(Tabanus nigrovittatus and T. lineola)* and sandflies or punkies *(Culicoides spp.)*.

2. NASSAU COUNTY. Nassau County Mosquito control is carried on by the Mosquito Control Division of the County Department of Public Works, under the direction of LeRay Kinsey, Deputy Commissioner for the Division. As in Suffolk County, the work is county-wide.

This county, being adjacent to New York City, is largely urbanized, and the population has grown very rapidly in the past 10 years.

The southern part of the county has large shallow bays containing some 145 salt marsh islands ranging in size from one acre to more than 50 acres. These islands have an effective system of ditches.

Adjacent to the upland along the bays there are about 10,000 acres of salt marsh on which have been dug almost 800 miles of drainage ditches. In addition, there are approximately 200 miles of upland streams and ditches to maintain for mosquito and flood control.

Besides the salt marsh problems, there are over 36,000 street catch basins that must be sprayed during the breeding season and some 2,500 other possible breeding areas listed, such as ponds, swampy pools, and low spots that must be inspected and treated.

For control purposes the county is divided into two districts, comprising 13 inspection areas, with an inspection spray crew and drainage maintenance crew assigned to each area.

Personnel of the mosquito control division varies from 100 to 140 year around. Over 50 pieces of motorized equipment such as trucks, cars, tractors, boats, mowers, and power sprayers are maintained.

In 1954 the mosquito population in Nassau was at a low level. The average daily catch in trap collections was only about 2 per trap.

Culex pipiens accounted for over 90% of the annoyance, and salt marsh and freshwater swamp species were the lowest that have been recorded.

During 1954, 13 mobile units and a marine unit made 51,280 inspection stops and performed 5,808 spray treatments for suppression of larvae, using 31,000 gallons of insecticides. Over 5,200 gallons of insecticide were used on space sprays for adult control. On the catch basins over 20,000 gallons of oil solution were used, in nearly 300,000 applications.

3. UPSTATE NEW YORK. In recent years, upstate cities, towns, and villages have become more articulate in their desire for the control of mosquitoes and other nuisance insects. The advent of insecticide fogging, although it has not always been the answer, certainly has been a powerful influence toward making groups aware that biting insects can be controlled. Then, once started on a program, it is sometimes easier to show the ultimate necessity for more basic, or at least less ephemeral measures.

In 1954 the upstate control program that had been under way the longest was the one directed primarily against blackflies in the Town of Webb. This program was made possible by the amendment to the State public health law passed in 1948, which states "The board of health of a town or village may take all necessary and proper steps for the control of mosquitoes, blackflies, punkies, ticks and other insects detrimental to health within their jurisdiction which may require community action for their destruction or control."

The Town of Webb blackfly control program is carried on with board of health funds set aside for the purpose, and administered by Dr. Robert Lindsay, the Town Health Officer. This program was developed with the participation and advice of the State Entomologist's Office of the State Science Service. All of the other blackfly control programs in the state have stemmed from the Webb township program, and, although on a smaller scale, are also organized on a township basis. Data on blackfly control in New York in 1954 are as follows:

TOWN OF WEBB. Program included airplane larviciding of over 200 square miles of rough mountainous country surrounding the populated areas, with supplementary fogging from a truck-mounted Tifa. The larviciding was done with a Piper Cub equipped with floats, flying parallel swaths one-quarter of a mile apart, plus topical applications, dispersing 20% DDT solution at the rate of 1 gallon per flight mile. Two applications were made, about 3 weeks apart, the first for *Prosimulium hirtipes* and the second for *Simulium venustum*. There was also an intermediate partial coverage of warmer streams. Approximately 900 gallons of 20% DDT solution were used.

The estimated total cost of these operations (including the flying contract at $1750) was about $2650.00. The supplementary fogging would add at least a thousand dollars to this cost. Plaster blocks and equipment maintenance costs would bring the total cost of the program for the year to a figure between $4,000 and $5,000.

FORESTPORT. Airplane larviciding of 100 square miles, using materials and techniques similar to those used in Town of Webb. The plane was a Piper Cub equipped with conventional landing gear. Total cost of operations and materials, $2,000.00.

BLUE MOUNTAIN LAKE. (A portion of the Township of Indian Lake.) Airplane larviciding of 50 square miles; two complete treatments and a partial third. Cost: $500.00, not including materials. Used same equipment as in Town of Webb.

LAKE PLACID. (A portion of the Township of North Elba.) Used same equipment as at Forestport. Two treatments over an area of about 100 square miles. Cost, including materials: $2750.00.

All the blackfly larviciding was done on a contract basis by the airspray operator who was awarded the contract after competitive bidding. Different factors were involved in arriving at a price for which operator was willing to do the work in the several areas, so that when the costs were later figured on the basis of gallons sprayed, they varied from one town to another.

The average operating cost of application was about $1.70 to apply one gallon, i.e., not including the cost of materials. If a materials cost of $1.00 per gallon is added in, we have the figure of $2.70 per gallon applied.

We would ordinarily figure on applying 1 gallon per flight mile. A square mile would be covered by 4 flight miles (i.e., 4 swaths a quarter of a mile apart) and would therefore require 4 gallons of larvicide. Using the average cost figures given above, we would arrive at a cost of $10.80 per square mile or 1.7 cents per acre on a regional basis as representing a reasonable workable figure for calculating costs of an airplane blackfly larval control program as practiced in 1954.

By the methods used as noted above, the over-all reduction in blackfly larval population, in about 50 streams checked in 1954, was 80%, which in most areas produced satisfactory control.

4. MOSQUITO CONTROL IN UPSTATE NEW YORK. Two upstate cities, both small ones, had organized mosquito control programs in 1954. There were a number of property owner groups, and many summer camps, which sponsored fogging and even some local larviciding. Several communities had occasional contract foggings and larvicidal spraying.

The cities of Ithaca and Geneva contracted with a local pest control operator to do their mosquito control. Since Ithaca is the site of Cornell University and Geneva of the New York State Agricultural Experiment Station, there were entomologists on hand whose advice was sought and, for the most part, followed. The programs consisted of early spring scouting to determine principal sources and then larviciding by means of a Buffalo Turbine. During the summer rather spotty scouting revealed water areas that had been missed earlier, and these were treated by hand. An effort was made to treat all standing water within each city and for half a mile beyond the city limits.

The pest control operators considered it to be more practical to set up a routine schedule of treating all probable areas than to scout first. The original amount estimated for the Geneva job (a city of 18,000 persons) was $1,000, but this was later increased to $2,500.00. Five larvicidal applications were provided for, but these were not applied uniformly.

One type of mosquito breeding situation that caused trouble around Geneva, and that was originally overlooked, was the pits left in the ground when nursery stock was removed. These pits were often filled with loose pruning brush to keep animals and children from falling into them. This prevented the pits from being seen in superficial scouting.

In the foregoing paragraphs, I have attempted to present the mosquito control picture in New York as it existed in 1954. If it appears that a relatively disproportionate emphasis was placed on certain biting flies other than mosquitoes, it should be brought out that in upstate New York there has been greater pressure for public control of such insects than for mosquitoes. The wording of the first law applying to control of nuisance insects specifically mentioned these other species. It is interesting to note that in areas where such insects as blackflies *(Simuliidae)* are controlled, a demand for mosquito and punkie *(Heleidae)* control is likely to follow. When requests from these areas plus requests from areas where mosquitoes are the primary nuisance become sufficiently numerous in any one county or in a geographically homogeneous area (i.e., the Montezuma swamp, which includes portions of 4 counties), it is probable that regional mosquito control on a continuing basis will develop.

MOSQUITO CONTROL IN PENNSYLVANIA

Russell W. Gies

Principal Sanitary Engineer and Consultant on Vector Control, Pennsylvania Department of Health

Mosquitoes and other insects affecting public health have been prominent in the history of Pennsylvania from the very earliest days of the settlement of the Commonwealth. The historical records of the early Swedish, Dutch, and English settlements along the Delaware River between Wilmington and Philadelphia, particularly, have had frequent reference to the great swarms of mosquitoes, flies, and other insects encountered. Early travelers from Europe coming to Pennsylvania throughout the Colonial period noted the excessive numbers of such mosquitoes and their effect on health as well as the annoyance that they caused.

Not much was done about this matter until the time of the first World War. At that time mosquitoes particularly became such an annoyance as to seriously interfere with the war efforts, particularly in the Hog Island Shipbuilding area and similar places. Control efforts were started under the direction of the Pennsylvania Department of Health, the United States Government, Westinghouse Corporation, and others on the Tinicum marshes. A large pumping plant was erected on land donated by the Westinghouse Corporation, and other measures were taken with a total expenditure of about $250,000.00 in 1918 and 1919.

After the first World War, intensive work was not continued, but with increasing recognition of the problem, in 1935, two County Mosquito Extermination Commissions were appointed following a referendum vote in Delaware and Blair Counties. This was as a result of the legislation passed and known as P.L. 226 of 1935. These County Commissions have carried on thorough and effective work, and the residents of both counties feel that the money appropriated each year has been well spent and that there has been a steady diminution of the number of mosquitoes.

At the time of the second World War, because of a production slowdown suffered by the United States Navy Aircraft plant at the Philadelphia Navy Yard and by many large industries in Philadelphia and Delaware Counties, renewed mosquito control efforts were carried on under the sponsorship of the Navy, the Philadelphia and Delaware County authorities, the United States Public Health Service, and the State Department of Health. As a result, the number of mosquitoes was reduced to a minimum; and work loss in production, which was estimated by the Chamber of Commerce to have amounted to about five million dollars annually, due to excessive number of mosquitoes, was practically wiped out by this organized effort.

It is worthy of note that the City of Philadelphia is expecting to expand its mosquito control work and will put a trained Entomologist in charge.

The problem of mosquito control in Pennsylvania is two-fold:

(1) Large areas of mosquito breeding occur in several places along the Delaware River, particularly in the Tinicum and Philadelphia marshes. There are also large marsh areas along the Moshannon River at Philipsburg in the center of the State; at Presque Isle, near Erie, in the Smethport and Port Alleghany sections, and in the lower Bucks County area where sewage pollution and construction pools have greatly intensified the amount of mosquito breeding, and other places. Bucks County is undergoing a tremendous development due to the location of the United States Steel Corporation's new Fairless Works in Falls Township, close to Trenton, and the starting of several large residential developments which will provide home for tens of thousands of new residents. Sewerage systems, road

construction, drainage, and other factors affecting mosquito breeding are never quite caught up so that the chance of breeding large numbers of mosquitoes in such places remains a serious problem.

(2) Thousands of smaller areas producing mosquitoes are spotted over the State; among these might be mentioned Gettysburg, Chambersburg, Sayre, and Athens, the Altoona and Tyrone areas of Blair County, the Ponoco region, many of the Philadelphia suburbs, the Allentown area, the Wyoming valley in the vicinity of Wilkes-Barre, and portions of the Schuylkill valley.

To sum up, the health and economic aspects of mosquito control include the reduction of disease, the increase of real estate and property values, and the enjoyment of outdoor recreation which may be secured through proper insect control at a very reasonable cost.

Because of the direct and indirect health problems involved, the Pennsylvania Department of Health has taken the lead in mosquito control through aiding other State Departments, municipalities, corporations, and individuals with consultative and advisory services.

The Pennsylvania Department of Health is aiding the program by:

(1) Supervision of airplane spraying at the request of the Pennsylvania Department of Forests and Waters of 70 miles of abandoned Schuylkill Canal and the airplane spraying of the Philadelphia and Delaware County marshes by the City of Philadelphia and the large landowners who are paying for this airplane work. The spraying is being carried out with the newly developed granular insecticides.

(2) The Department is also cooperating in the placement and operation of a considerable number of insect light traps throughout the State for studying the distribution of the various species of mosquitoes, the numbers in each area, etc. In areas where control work is being carried on, the light traps catches are of considerable help in checking the results of the control operations and in uncovering weak points. In areas where such control is not yet started, the data will be of considerable benefit in planning such future operations.

(3) Close cooperation is also being maintained with the two active County-wide mosquito control commissions and the work carried on by a total of about 300 communities in the State. Approximately $250,000.00 yearly is being spent to protect 1,500,000 people living in these communities where organized control of some kind is being carried out.

(4) The department has advised the State Park System, which operates 109 State Parks, regarding health related insect problems. Millions of visitors to these State Parks are affected by insect breeding.

(5) About 100 owners of large camps for both children and adults in the Pocono area and other points in the State have been advised regarding mosquito, fly, and other insect control problems, and close cooperation is maintained with these groups from year to year.

(6) The Department is sponsoring and helping to direct a large new cooperative control program in Bucks County that will aid nearly 150,000 people. In two years, the work of this cooperative Bucks County Mosquito Control Commission, financed by State, County, and municipal funds and contributions of private corporations and individuals, has produced a definite reduction of mosquitoes.

(7) Advisory service is given concerning requests for information from the general public, municipalities, etc., for insect control and sanitary landfill data which is closely allied to mosquito control work, and liaison is maintained with the local health departments throughout the entire State regarding such problems.

The public health insect control work carried on by the Department is meeting a real need, and is one of the services of the State that has proven to be extremely worthwhile.

NEW JERSEY MOSQUITO CONTROL PROGRESS

Bailey B. Pepper, *Head*
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New Brunswick

Mr. Chairman, members of the California Mosquito Control Association and American Mosquito Control Association, and friends. It is needless for me to say that it is a real pleasure for me to appear personally in California. It is indeed a pleasure to be here representing the New Jersey Mosquito Extermination Association and to bring you greetings from that group, and especially from President Sutphen who instructed me to extend his best wishes to both societies for a very informative meeting. I also might add that the New Jersey Association will hold its 42nd Annual Meeting in Atlantic City on March 9, 10, and 11, and I have been asked to extend a most cordial invitation to each and every one of you to meet with us at that time. I hope that many of you will find it possible to attend.

Within the brief time limit allowed this morning, I will not attempt to give you more than a very brief summary of the mosquito control activities in New Jersey during 1954.

It is rather difficult to separate the different agencies, so I will only speak of the state as a whole. We have a state association which is very much interested in mosquito control. There are 15 county mosquito extermination commissions who are carrying on active programs. Associated therewith are the research activities of the New Jersey State Agricultural Experiment Station. Also, the Agricultural Experiment Station is charged by law with the responsibility of approval of plans and estimates of the county commissions, as well as coordinating the several county programs. Please remember that there are three groups working together and I do not intend to slight any one group.

From the Association standpoint, I might add that the American Mosquito Control Association met jointly with the New Jersey Mosquito Extermination Association in 1954 and published joint proceedings, copies of which were mailed in December to all members of the American Mosquito Control Association and we hope everyone has received them by this time. It comprised a book of 312 pages and all papers which were presented at the conference were printed in the Proceedings except a very few which had previous commitments for their publication.

In general, the mosquito annoyance was at a low level throughout the state in 1954. We had one of the driest summer seasons on record, not only dry for the summer, but it started much earlier than normal. The drought, however, did cause some unusual problems in some of the counties. Many streams were so low that there was not sufficient flow to keep the mosquitoes flushed and as a result, pools formed and larviciding became necessary in a great many areas. Because of the drought we had some rather unusual situations with street catch basins. Usually they are flushed from heavy rains but because of the drought condition, there was rather heavy breeding in many areas.

We also experienced a rather unusual situation in the late fall in that the weather or rains in September gave us some problems with late breeding. Some of the breeding continued up into October. However, the annoyance was not too severe since at that time of year people are not outdoors in the early evenings when annoyance is greatest.

During the past 10 years the mosquito problem has materially changed in New Jersey. Prior to that time our primary problem was with salt marsh species. In the last 10 years the problem has been with the domestic species, the *Culex* complex. This condition has been brought about by some unusual changes that have occurred in New Jersey as elsewhere in the nation, namely great industrial and residential expansion. In these expansions some of the problems that go along with such changes have not kept pace, particularly surface water drainage and the sanitary sewer problems. As a result of industrial and residential growth, these problems have crept in and have given the state considerable trouble.

I also might add that over the years the New Jersey folks have held firmly to permanent measures of control. Realizing that permanent measures are rather costly and long drawn out in those areas where the permanent measures cannot be made for economic reasons (appropriations), temporary measures of larviciding and adulticiding have been performed. I think there is a place for all types of control.

In recent years a number of the counties have been called on to carry a greater load than just mosquito control. Other nuisance problems have been added, leaving us somewhat in a quandary as to just how far these extra activities should go since the counties are working strictly under the mosquito control law and it is specifically stated as "mosquitoes." The question arises: how far afield should mosquito extermination commissions go? I do not believe we have the answer to that at the moment, but it is something that we will have to give consideration to in the not too distant future.

Just a few remarks about some of the newer activities. We have carried on an adult spraying program with aircraft for the past 5 years. In 1954 some 23,000 acres were sprayed for adult mosquito control. We are beginning to ask the question: What results are being obtained? I think the results have been far beyond our highest expectations, and we are now wondering if the adult spray program is not killing off enough of the adults along the salt marsh region to affect egg deposition and, consequently, larval breeding. That is just an indication. We do not have the answer to the question at the moment.

Another very important part of the activities in New Jersey has been the cooperation with other agencies. For example, this past year the Department of Entomology of the station has cooperated with the Department of Defense in the State; the State Fish and Game Council; the United States Public Health Service; the New Jersey State Department of Health; and other state agencies, such as the New Jersey Turnpike and the Garden State Parkway Authorities.

I would like to mention some of the highlights of our research activities during the past year. Dr. Ginsburg has continued investigation with some of the newer insecticides that might offer promise. Dr. Hagmann has continued his studies on the biology and ecology of several species of mosquitoes of New Jersey which are not too well understood, and we hope that in the very near future there studies will enlighten us as to possible short cuts in mosquito control. Another rather interesting study which has been carried on by one of our students in cooperation with Mr. Jobbins is the study of the chemical and physical properties of granular insecticides. This study has revealed some very interesting information which will have rather important effects in the future.

During the past season a project, supported by United States Public Health Service funds on vector-encephalitis relationship studies in birds, was initiated.

We recognize that in this whole mosquito control problem research has been neglected and that if we are to keep pace with the problem, we must devote more time to that segment of the work.

In addition to the mosquito work, our department of entomology is looking at this whole picture of insect control from a little different angle than we did for the past several years. We believe we are at the point where we are going to have to dig deeper and study some of the fundamentals of the organism and its way of life—particularly on how insecticides affect it. We do have a rather broad program going along that line at the present time, and I hope that it will begin to produce new knowledge that will enable us to increase our effectiveness in mosquito control.

I thank you very much.

MOSQUITO CONTROL ACTIVITIES IN VIRGINIA

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In 1607 a band of hardy Englishmen landed at Jamestown on the shores of Virginia and established the first English colony in the New World. History tells us that after a year or two the colony moved to higher land at Williamsburg, due to fever. There is little doubt today that this fever was malaria. For over 300 years, up until the mid 1930's, malaria continued to take its toll in the Old Dominion State, striking many dead, and making a resident who had never had the chills and fever a rare specimen.

In the summer of 1855 a yellow fever epidemic hit Norfolk and Portsmouth, and in a short eight weeks the population was reduced by two thirds. In addition to the sickness and death that mosquitoes have left in their wake in Virginia, it is impossible to estimate the discomfort and misery that pestiferous mosquitoes have caused.

It is gratifying to report that things have changed. No longer are mosquitoes a direct menace to health. Yellow fever has not been reported in many years, and a single case of indigenous malaria would really cause quite a commotion. Great progress has also been made in certain sections towards reducing pest mosquitoes.

Eastern Virginia is a low coastal plain known as Tidewater. It extends along the Atlantic Ocean and Chesapeake Bay and back inland along the several rivers. It is interesting to note that Richmond, 100 miles inland, has a seaport terminal. From the fall line to the mountains, there is a section known as Piedmont, which is rolling country. Farther to the west are the Alleghany mountains. From time to time, minor and local domestic mosquito problems exist in other parts of the State; but, by and large, the major problems are in Eastern Virginia.

At the entrance to Chesapeake Bay exists one of the finest harbors in the world. One-sixth of the State's population live within a forty mile radius, including the Cities of Norfolk, Portsmouth, South Norfolk, Newport News, Hampton, Warwick, Williamsburg, Suffolk, Franklin, and Virginia Beach and the Counties of Princess Anne, Norfolk, and York. Because of the fine beaches, the historical shrines, and the several military establishments, thousands of additional persons are attracted to the area each summer.

It is in this area that mosquito control efforts are principally directed. The problem generally can be classified into four types of mosquitoes to be controlled:

(1) The salt marsh and brackish water mosquitoes *(Aedes sollicitans, Aedes taeniorhynchus, Anopheles crucians bradleyi,* and *Culex salinarius).*

(2) the upland fresh water mosquitoes *(Aedes vexans, Aedes canadensis, Mansonia perturbans).*

(3) The temporary rain pool breeders *(Psorophora ferox, Psorophora confinnis).*

(4) The house mosquito *(Culex pipiens, Aedes aegypti).*

In the low flat land with an annual rainfall of forty-three inches, standing water is a common thing. As many as 100 breeding places occur in an area the size of one city block.

Methods of control vary with each situation. Filling is encouraged wherever possible, but of course the cost makes its use very limited. Drainage and ditching are by far the most important mosquito control tools. Larviciding is used extensively, using hand spraying, power spraying, and airplane spraying; and, because of the climate, this must be carried out on a seven day schedule throughout the summer months. Fogging and misting are also used to supplement other methods of control; but because of its temporary effect, its high cost, and the possibility of building up resistant mosquitoes, its extensive use is not encouraged.

Fourteen mosquito control districts have been established in Virginia under a State Enabling Act. Under this law, the local governing body of a city, town, or county, alone or together, can create a mosquito control district to include all or a part under their jurisdiction. The local administration appoints two members to serve on the mosquito control commission, and the third member (exofficio chairman) is the State Health Commissioner or his deputy. The commission is responsible for carrying on the control measures and is given wide power, even to that of eminent domain. Funds with which to operate come from local taxes or appropriations, and the State contributes a sum equal to 25% of the funds raised locally, but not to exceed $10,000 in one year.

Pest mosquito control as such is an economic problem. The people living in an area must be awakened to the need for mosquito control, and they must be willing and able to pay for it. Most of the areas in Virginia where a mosquito problem exists and where there is sufficient population are now organized into mosquito control districts. There still remains many areas where the mosquitoes are as bad as they ever were, but because of the sparse population, control cannot be justified at this time. In the future, as the beautiful shoreline of Eastern Virginia is developed, mosquito control operations will be expanded.

Mr. Mulrennan: Mr. Chairman, members of the American Mosquito Control Association, and California Mosquito Control Association: I can assure you it is really a privilege to have this opportunity to come to California for the first time. I would like to first pay my respects to the old War Horse (Harold Gray) sitting over there to my left, but there is one thing that I want to say now. He told me a story the first time I ever saw him in Florida; I just found out yesterday that his story was partially true. He said to me, "John, do you know how Lake Okeechobee was formed?" I answered, "No, I do not believe that I know." "Well," he said, "about 50 years ago California was transporting a grapefruit to Miami to place it in an exposition. The grapefruit fell from the plane just outside of Miami and—so today you have Lake Okeechobee."

Yesterday I went out and I found a California grapefruit and for about 15 minutes I cut on it. After I got through the rind, which was about 3 inches thick, I found a little juice inside. Upon squeezing it, I was able to produce about a tablespoonful of juice. So, I am sure that the California grapefruit that fell off of the plane might have made the hole which today is Lake Okeechobee, but it certainly did not put the water in the Lake.

THE STORY OF MOSQUITO CONTROL IN FLORIDA

J. A. Mulrennan, *Director, Bureau of Entomology, Florida State Board of Health, Jacksonville, Florida*

Florida could be classed as the Crown Jewel of the North American Continent, in that it stands out as a shining light by the brilliance of its sunshine and by the pointed fact that it is a peninsula, giving life to a luxurious flora and to an abundant fauna.

It would seem natural that the Great Creator should have guided the first explorers to the land of sunshine and flowers with all of its splendor and beauty which became a mecca for the naturalists in the early days following her discovery.

The cradle of American democracy with its pearly white beaches bathed by the blue-green waters of the briny deep surrounding the great paradise now known as Florida also was to experience the bitter with the sweet.

Around a century ago when the Statehood of Florida was being debated in Congress, the Honorable John Randolph of Virginia rose to state that Florida could never be developed, nor would it ever be a fit place in which to live. He described it as "a land of swamps, of quagmires, of frogs and alligators and mosquitoes." Truer words were never spoken. There were dark days as far as human existence was concerned. The State at the time (1845) had a population of 66,500 with the greatest percentage to be found in the northern part of the State.

Each summer yellow fever and malaria would sweep through the villages like a forest fire. The year 1857 will be long remembered as the year of the great pestilence. It was reported that approximately six hundred persons in Jacksonville had yellow fever and that one hundred and twenty-seven died.

In 1877 Fernandina with a population of 1632 was to experience one of the greatest holocausts to ever strike this section of Florida. In the summer of 1877, 1146 people were sick with fevers. In answer to the call to physicians for aid in the catastrophe, Dr. Francis Preston Wellford, president of the Florida Medical Association, volunteered his services, and on September 22 left Jacksonville for Fernandina never to return. On October 10, at ten o'clock in the morning, Dr. Wellford died of yellow fever.

In 1887 yellow fever epidemics occurred in Key West, Tampa, Plant City, and Manatee. In 1888 the disease broke out in Jacksonville, causing an exodus from the city in carriages, drays, and wagons laden with people streaming toward the depot and the docks, while every outgoing train and steamer was crowded beyond capacity. On the night of November 25, the temperature fell to thirty-two degrees, and thereafter the epidemic was virtually at an end. Thanksgiving was not as happy an occasion in 1888 as it had been in 1877, however, for the city had suffered a much more devastating experience. Nearly five thousand had contracted the disease, and more than four hundred had died.

The epidemic of yellow fever in 1888 brought about the creation of the State Board of Health in 1889. As early as 1873, a half-hearted attempt to organize a State Board of Health was made when Senator Howe introduced a bill in the State legislature asking for an appropriation of two hundred dollars.

Dr. John P. Wall of Tampa might be called the father of the State Board of Health. He stated in an address in 1875 before the Florida Medical Association: "The time is fast hastening when the preservation of the public health will become one of primary consideration in all enlightened governments."

The early settlements of Florida were almost entirely within the area later defined as the "malaria belt." Tallahassee, the State capitol, was in the midst of this region.

The final knockout came to yellow fever in 1905. Dengue fever apparently got its paralyzing wallop in the mid-thirties and malaria made its final bow at Naples in 1948.

The direction of approach to the control of malaria was recognized in Florida as early as 1900 by Dr. Porter, the first State Health Officer, when he stated, "It was observed that the attacks (of malaria) were more than usually fatal along the river bottoms, marsh lands, and in flat woods country... It now is seen that it is not the germ itself which rises from the soil or water but the *carrier of the germ.*"

However, despite this early recognition of the means at hand for controlling malaria, no concerted effort was made in this direction until the World War I period. At this time drainage and larvicidal measures were introduced at Camp Johnston in a joint effort of the Army, U. S. Public Health Service, and State Health Department, as a part of the general sanitation program around military establishments.

After this initial start, the State Health Department undertook its first malaria control project, in the City of Perry, a typical malarious community in Florida. At that time it was one of the largest projects of the kind in the country and involved the removal of 47,000 cubic yards of earth for drainage canals and ditches at an expenditure of $28,000. The cost of the project was borne by the City of Perry, the county of Taylor, and the Burton Swartz Cypress Company, with the State Board of Health supplying the technical supervision. A subsequent letter from the lumbering plant stated that they had been more than repaid for their share of the cost by increased output resulting from the better health of their employees.

The first great forward step in the control of mosquitoes in this State was the organization of the Florida Anti-Mosquito Association in 1922 by the State Board of Health. Dr. Porter became its first president. This organization has performed a momentous duty in the promotion and coordination of the mosquito control activities in the State.

The first mosquito control district was established by vote in Indian River County in 1925. At the end of 1953 there were 23 mosquito control districts in 21 of Florida's 67 counties. In addition to the 21 counties having organized mosquito control districts, arthropod control is carried on by 23 additional counties, and the work is administered by the boards of county commissioners and directed by the county health departments. One small county, Brevard, with a population of 25,570 in 1950, appropriated $208,649 for mosquito control for the fiscal year 1953-54. Indian River County, a small county, has a per capita tax for mosquito control of $9.11, and Dade County (Miami), the wealthiest and most populous, has the lowest per capita tax of 17 cents.

All mosquito and arthropod control is directed at the local level by an individual under the supervision of the mosquito control board, or the Board of County Commissioners, elected by the people.

All boards are required by law to submit a plan of operation to the State Board of Health annually before expending their own funds, or before receiving aid from the State. In order to assist the local boards with their administrative and technical problems, the State is divided into four operational district. Stationed in each district are an engineer and an entomologist who are responsible for the arthropod control in an assigned number of counties.

Each board also is required by law to report each month on all county and State expenditures for mosquito control, as well as reporting at the end of each month on all of their operational activities.

The first State law on mosquito control was passed in 1925, making it possible for a county to vote for a mosquito control district and for the residents to tax themselves for the work. Another State law was enacted in 1929, and in 1941 the Legislature provided for three alternate methods for establishing mosquito control districts in the State.

The first State law providing for State aid to counties and mosquito control districts was passed in 1949. This law provided that aid be given by the State Board of Health to mosquito control districts and county health departments in the form of insecticides, materials, equipment, personnel, and trucks in amounts not to exceed $15,000 annually to any one county. This law, for the first time, recognized pest mosquitoes and other non-disease-bearing arthropods as being of public health and economic importance. A total of $350,000 has since been made available each year under this law by the State legislature for the control of mosquitoes and human-biting flies .

In 1953, upon the recommendation of the Florida State Board of Health, the State legislature passed a second State aid law whereby any board of county commissioners or a mosquito control district that places funds in its budget for the control of "arthropods of public health importance," would receive funds directly from the State upon proper certification by the Board of Health, amounting to 75 per cent of the total funds appropriated by the county or district. This law stipulates that State funds are to be used exclusively for the permanent eliminative measures such as sanitary landfills, filling and draining of breeding areas, the purchase of all types of equipment, the hiring of personnel, and the operation of equipment to be used in carrying out permanent measures of arthopod control. The legislature appropriated $1,250,000 annually for this program, in addition to the annual appropriation of $350,000, for both permanent and temporary control measures. In addition to the direct aid to counties and mosquito control districts, this law provided an additional appropriation of $250,000 a year to be used by the State Board of Health for administration, consultation, and for the construction and operation of a research laboratory. The State of Florida is, therefore, at present appropriating a total of $1,850,000 annually for the control of mosquitoes and other arthropods of public health importance. Local appropriations for 1953-54 amounted to $1,464,105, and direct Federal funds through the Public Health Service amounted to $8,000 making a total of $3,322,105 available for this purpose during the past fiscal year. At the present time the State receives no aid from the Federal Government.

It is my feeling that we are developing one of the soundest arthropod control programs in the country, wherein balance is found in its control procedures. There is developing close coordination between the State and county which must prevail if efficient, effective, and uniform control is to be carried out in all counties.

The many different kinds of arthropod problems makes it mandatory that the research program become an integral part of the overall control program.

The present Governor, LeRoy Collins, has been a friend of mosquito control legislation since the passage of the 1949 law. He has recommended that we try and combine the two mosquito aid laws. This also has been recommended by the State Health Officer. This will give us an opportunity to draft an excellent bill out of two good laws at the present time. (Note: The law was passed by the legislature which met after reading this paper).

The tourist industry is the largest industry in Florida and in 1953 brought in $950,000,000. It is, therefore, important that the State do all in its power to protect the health as well as the comfort of its visitors. Furthermore, the permanent residents of the State are not unappreciative of the benefits to themselves of a vigorous program against mosquitoes and other pestiferous arthropods. Florida today is one of the three fastest growing states in the Union—the present population is 3,500,000, and it is estimated that in the next fifteen years at the present rate of growth, the State will double its population. The rapid growth, flood control, pollution of lakes and streams, and many other factors are bringing about untold arthropod problems without an economic solution as to control.

The Florida State Board of Health, in order to assist it in solving the many arthropod problems confronting the State, has under construction a biological research center in Indian River County on the southeast coast of Florida. It is expected that $215,000 will be utilized in constructing and equipping the laboratory. In subsequent years it is planned to utilize about $150,000 a year for research, and approximately $125,000 is to be used in administering the mosquito and structural pest control laws, and in giving technical assistance to the counties.

The purpose of the Research center will be twofold: (a) to produce the biological information the State Board of Health needs to promote and carry out the most effective and efficient control program possible, and (b) to expedite the incorporation of this information into control practices. The research center will be intimately connected with the control operations in all districts and counties, and thus practical needs will direct its research efforts.

SECOND SESSION

1:30 P.M., MONDAY, JANUARY 24, 1955
SIERRA ROOM, HOTEL STATLER

This session of Invitational Papers covering key developments pertaining to mosquitoes and their control during 1954, was called to order by President Rowland E. Dorer of the American Mosquito Control Association from Norfolk, Virginia.

A REVIEW OF RECENT PROGRESS IN MOSQUITO STUDIES IN CANADA

C. R. Twinn

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ABSTRACT

Progress in studies on mosquitoes in a biting-fly research program in Canada is reviewed and references are given to recently published and some unpublished work. The subjects dealt with include: the systematics and distribution of Canadian species; attempts to rear laboratory colonies of northern *Aedes;* the relation of the immature stages to their environment; the behavior of adult mosquitoes in relation to meteorological conditions; dispersal and flight range; the food of the adults; the responses of female *Aedes* to various factors relating to their hosts; and studies of biological and chemical control, and of repellents.

About 63 species of mosquitoes have been recorded in Canada and many new distribution records obtained from various sources, including the Northern Insect Survey, which so far has covered more than 50 arctic and subarctic localities. Recent contributions to the systematics of Canadian mosquitoes are described.

Attempts to establish continuous laboratory colonies of northern *Aedes* have not yet succeeded, but valuable progress has been made and useful biological information obtained on the species studied. Relations between mosquito development and environmental conditions in the Churchill region have been established and formulae suggested for predicting mosquito emergence in a permafrost, forest-tundra transition area. Field studies have been completed on the relation between the activities of adult mosquitoes and meteorological conditions, and papers presenting the results are in preparation. Recent work on the problem of mosquito dispersal and flight range is described, including (1) the release and collection of specimens marked with radiophosphorus, (2) a study of the power requirements and efficiency in utilizing energy in flight of mosquitoes and certain other insects, on which are based estimates of distances they might travel and their possible speed of flight in still air, and (3) observations on the flight behavior of mosquitoes which indicate that their reactions to certain meteorological conditions cause them to lose visual contact with the ground and fly with the wind, a possible explanation of mass movements of the insects over long distances in prairie or tundra.

Mosquitoes and many other biting flies have two distinct forms of food: both sexes take carbohydrates, usually as nectar, for energy, but the females also take protein, as in blood meals, for egg production, or obtain it from other specified sources.

Studies of the responses of female *Aedes* mosquitoes provided information on the behavior of the insects in relation to their hosts, reported in a series of papers. Recent work dealt with the effects on mosquito attack by warmth, colour, moisture, and sweat of the human host and of the colour of his clothing.

Progress is reported in an investigation of natural enemies of mosquitoes, including nematode and protozoan parasites and aquatic insect predators.

Chemical control of mosquitoes is generally carried out on a modest scale by cities, towns, and smaller communities in Canada, and by military and other agencies. Tests indicated that mosquitoes in southern Ontario were not resistant to DDT, and this was not a factor in reported unsatisfactory control in that region. Reference is made to the development and testing of aerial and ground equipment for dispersing insecticides against biting flies and the testing of repellents.

AEDES AEGYPTI AND MALARIA ERADICATION PROGRAMS IN LATIN AMERICA

Dr. Fred L. Soper, *Director*
Pan American Sanitary Bureau
Washington, D. C.

Having been introduced as the Director of the Pan American Sanitary Bureau, I must reintroduce myself also as the Director of the World Health Organization for the Americas.

It would be a mistake to let this meeting pass without a word of propaganda on the International Health Organizations. The Pan American Sanitary Bureau, supported by all of the nations of the Americas except Canada, is one of the specialized agencies of the Organization of American States. On the other hand, the World Health Organization of the United Nations is supported by all of the American nations except Colombia. In the field of health, and only in this field, has it been possible to bring together the activities of the specialized agencies of Inter-American and World Systems. The Pan American Sanitary Bureau and the World Health Organization are working in the Americas with multiple financial support, but as a single operating unit. In the presentation today I shall speak of programs, some of which are supported by the Pan American Sanitary Bureau, some by the World Health Organization, some by Technical Assistance Funds, and many by the United Nations Children's Emergency Fund.

The official international health agencies (Pan American Sanitary Bureau and World Health Organization) participate in mosquito control only for the prevention of disease. Control of pest mosquitoes is a luxury for many regions where Yellow Fever and Malaria are still important problems.

The orientation and extent of anti-mosquito measures depend on their objectives, and these objectives we might classify as—

1. The local reduction of disease,
2. The eradication of disease, or
3. The eradication of a vector mosquito.

The objectives of anti-mosquito measures related to Yellow Fever have varied as knowledge based on experience has accumulated. For example, the original work of Gorgas in Havana and Panama and the work of Oswaldo Cruz in Rio de Janeiro was for local Yellow Fever control. Eventually, it was noted that once local control was obtained in the larger cities, Yellow Fever tended to disappear not only from those cities but also from surrounding areas. And beginning in 1915, the Rockefeller Foundation collaborated in anti-mosquito campaigns whose declared objective was nothing less than the complete eradication of Yellow Fever as a disease from the Americas. This campaign was carried out on the basis of a temporary reduction of the breeding of the *Aedes aegypti* mosquito below the threshold of continuing transmission of Yellow Fever in the large centers of population in the endemic areas.

Once the infection had died out in the human host, it was anticipated that, unless Yellow Fever virus should be reintroduced from Africa, the Americas would remain permanently free of the disease. The early campaigns were highly successful, and by 1934 the last endemic focus of the *aegypti*-transmitted Yellow Fever in the Americas had been cleaned out.

The observation in 1932 of Yellow Fever in the absence of *aegypti* led to the discovery of Jungle Yellow Fever as a permanent source of virus for the reinfection of cities and ports. Fortunately, this finding coincided with the demonstration that the reduction of *aegypti* breeding could be carried to eradication of the species in Brazilian cities. Unfortunately, that discovery hasn't led to the eradication of *aegypti* in the cities of the United States.

The campaign for the eradication of Yellow Fever in the Americas, by the temporary reduction of local *aegypti* breeding, became a long term program, first for Brazil and Bolivia and later, in 1947, under the auspices of the Pan American Sanitary Bureau for the Western Hemisphere, for the permanent protection against urban and maritime Yellow Fever by the complete continent-wide eradication of the *Aedes aegypti* mosquito.

The objective changed then, in the case of Yellow Fever, first from local control of Yellow Fever to continent-wide eradication of Yellow Fever, and second, from eradication of Yellow Fever to the continent-wide eradication of the domiciliary vector of the Yellow Fever, the *Aedes aegypti* mosquito.

In the case of Malaria, the objective of anti-mosquito measures until recent years was the local reduction of *Anopheles* breeding below the threshold of Malaria transmission for the protection of the population of limited areas. Health workers had to be content with costly efforts of control in suburban areas, in villages, and in densely populated rural areas. There was no method available for the control of rural Malaria in the tropical areas which are sparsely populated.

The invasion of Brazil by *Anopheles gambiae*, the most dreaded of the African vectors, led, in 1939, to anti-mosquito measures for the eradication of this species from North East Brazil. The success of this campaign led to a similar campaign in 1944 for the eradication of *A. gambiae* from Egypt which had been invaded with disastrous results in 1942. The eradication of *A. gambiae* from Brazil and Egypt was followed by other campaigns whose objectives were the eradication of mosquito vectors, namely; *Anopheles sargenti* from the oases of the Western desert of Egypt, (Kharea and Dahkla) of *Anopheles la-*

branchiae from Sardinia and *A. sacharovi* from Cyprus and of *A. funestus* and *A. gambiae* from Mauritius.

With the introduction of DDT as a residual insecticide, the prevention of Malaria transmission in sparsely settled rural areas, although still expensive, has become economically feasible. The almost miraculous reduction in Malaria obtained with DDT and other residual insecticides during the past decade has led to a complete revolution in the objectives of antimosquito measures for the control of Malaria. Local programs for Malaria control and campaigns for vector eradication of the Malaria plasmodium itself, in the human as well as in the mosquito population. Nation-wide campaigns, in turn, are becoming a regional undertaking, and eventual world-wide eradication is the ultimate obvious objective. This revolution in objectives has occurred because of the selective action of the residual insecticides on the *Anopheles* mosquito within human habitations, before or after contact with the gametocyte carrier.

In the absence of infected mosquitoes, transmission ceases, and in a comparatively short period of time the infection dies out in the human host. Once this has occurred, further transmission can take place only after the immigration of gametocyte carriers.

Factors which have influenced very strongly the change in objectives are the observation in many countries that the funds for continued application of residual insecticides, year after year, are difficult to secure, once the initial reduction of Malaria has occurred, and the much more serious finding in some areas that the *Anopheles* have become resistant to DDT after several years of exposure. Added to these considerations is the almost certain shortage of insecticides which must be anticipated in case of any major armed conflict in the world. Following the beginning of the Korean conflict, there was a period of about a year in which it was most difficult to get free movement of insecticides to countries which were dependent upon them. So the eradication of Malaria, as a disease, is of the greatest urgency while residual insecticides are still potent and available.

To be successful, the eradication of Malaria must cover a sufficiently large area to guarantee against frequent reintroduction of the infection from still endemic regions. Once eradication is undertaken, Malaria is no longer a matter of interest only to the local community, not even to the nation where it exists, but is of regional and even world-wide concern. In a similar way the development of resistance in an *Anopheles* vector in any country must be a matter of concern to those other countries to which this resistant species may spread.

The United States was one of the first nations to undertake and accomplish the eradication of endemic Malaria. During the past 4 or 5 years, there have been practically no cases of Malaria transmission in the United States which have not been quite clearly attributable to the introduction of the infection from outside the country. The United States is actively supporting the proposal for the eradication of Malaria from all the countries and territories of the Western Hemisphere.

The XIV Pan American Sanitary Conference (Santiago, Chile, October, 1954) recommended as an emergency program, the transformation of all Malaria control programs in the Americas to eradication programs as rapidly as possible.

And so, at the present time, the Pan American Sanitary Bureau which also serves as the Regional Office of the World Health Organization, is actively attempting to coordinate two continent-wide antimosquito programs with completely different objectives; the one for the eradication of the *aegypti* mosquito as the urban vector of Yellow Fever.

In 1947, Brazil, at the time it had practically completed the eradication of *Aedes aegypti* and was being reinfested from the surrounding countries, took the initiative in proposing the program for the eradication of *aegypti* from the rest of the continent. Interestingly enough, it is the United States which has not participated in the eradication of *aegypti* which is taking an active lead in proposing the eradication of Malaria from the rest of the continent.

Latin American health workers have noted these diverse attitudes of the United States towards the two problems. In any case we owe to the United States the demonstration that this country could be cleared of Malaria, a most important landmark in the development of the malaria eradication project.

From a map of South America, it will be seen that Brazil has frontiers with ten (10) different political units from which it would be readily reinfested with *aegypti*. Hence, Brazil was very much interested in getting the collaboration of the other countries for the eradication of this mosquito. The discovery that *aegypti* could be eradicated from the towns of Brazil was first made in 1932 to 1933. Progress has been constant, and during the past 5 or 6 years there has been no known continuing infestation in Brazil, all of the towns and cities where *aegypti* was previously known to be present having been cleaned up. Only rarely do surveys of scattered interior areas reveal isolated houses still infested. Such infestations are rapidly liquidated with DDT. Brazil is a large susceptible region where *aegypti* has been, for all practical purposes, eradicated.

Bolivia has had no *aegypti* since 1948. Paraguay is clean so far as can be determined.

The interior of Uruguay is clean, and the results of what may well be the final revision of the capital city of Montevideo are negative.

Chile is also no longer infested with *aegypti*, so that in the southern two-thirds of the continent, only the problem of *aegypti* in Argentina remains. Argentina has been slow in getting started on *aegypti* eradication, but this was anticipated in 1947. It was then predicted that the last two countries to get interested would be Argentina and the United States. Argentina has definite plans for the organization of the anti-*aegypti* eradication program in April, 1956.

Peru has not reported finding *aegypti* for some time, but the final revisions have not been made there.

Ecuador has had no *aegypti* since about 1949 or 1950, except for a single spot along the frontier with Colombia.

Colombia is estimated to have its program of *aegypti* eradication about half finished.

Venezuela has been working on *aegypti* eradication since 1948, but the capital city of Caracas was not included until after the arrival of an infectious case of Yellow Fever in 1954, the first to be recognized in the city since 1914. Undoubtedly, the anti-*aegypti* campaign will now be intensified until eradication is achieved.

Another important situation developed last year in Trinidad. Since 1948 the Pan American Sanitary Bureau has been attempting to collaborate with the authorities in Trinidad in the eradication of *aegypti*. Trinidad had not had any reported Yellow Fever since 1914, but in 1954 they had Yellow Fever; not only as a jungle disease with monkeys, but they also had it as an urban disease transmitted by *Aedes aegypti,* and for the first time in 25 years a port in the Americas was declared an infected port with Yellow Fever as an *aegypti* transmitted disease. The cost and the expense and the loss entailed by this declaration was almost unbelievable, with estimates running as high as $23,000,000. But in any case, Trinidad and Caracas are now being cleaned up, and within a few more years at the most the American continent should be completely free of *aegypti.*

Coming close home, Panama and the Central American countries are very largely free of *aegypti.* There is still some *aegypti* in Guatemala, still some in El Salvador, possibly a few in Honduras, but all of those places are being worked.

In the Islands it is noted that Jamaica, Puerto Rico, Cuba, the Dominican Republic, and Haiti are all actively working on the problem.

The most difficult *aegypti* problems at the moment are those in Mexico and in the United States. Yellow Fever has been moving up through Central America in an epizootic wave among the animals since 1948. It has moved through Panama, Costa Rica, Nicaragua, Honduras, and Guatemala. If it crosses this frontier, the disease might well be present as an animal disease in Mexico within the next year and a half or two years. The recent newspaper reports of Yellow Fever in Mexico have not been confirmed.

Cuba has organized a serious program for the eradication of *aegypti;* and once Havana and the Island of Cuba are free, considerable pressure may be placed on authorities in the United State to undertake eradication here.

The movement, since 1948, of Yellow Fever virus as an advancing epizootic wave through Panama, Costa Rica, Nicaragua, and Honduras, towards Guatemala and Mexico, and the occurrence of both jungle and urban Yellow Fever in Trinidad in 1954, are but the dramatic highlights to the continuous background of jungle Yellow Fever activity in various countries of South America, and all within a few hours travel by plane from the United States. The continued presence of the *Aedes aegypti* mosquito in the cities of the United States represents not only a potential danger here but a source of reinfestation by this mosquito of neighboring countries which are so actively engaged in a coordinated campaign for its eradication.

Very soon after DDT became available the largest geographical areas involved in the Malaria problem in the Americas made serious attempts to bring it under control. The United States, Venezuela, Brazil, and Argentina are four countries which have done a tremendous job and have really made considerable progress in the eradication of Malaria from the largest part of the Americas.

Venezuela has an area of 80,000 square miles in which no local transmission of Malaria was reported during the past four years. Brazil's program is on a scale for 1955 requiring the purchase of DDT amounting to about $1,500,000. Argentina has covered practically all of its area. There is still some importation of Malaria from Bolivia and some areas where epidemic Malaria may occur in the future.

British Guiana is one of the outstanding successes where Malaria has been eradicated, and French Guiana has been equally successful in completely eradicating Malaria. The reports from French Guiana are very similar to those of the United States in indicating that such Malaria as occurs today can be traced to reintroduction immediately preceding the infection.

Without going into detail on other individual countries, one can say that among the two chief problems in the Malaria eradication are Colombia, because of the difficulty of the terrain, and Mexico. Mexico, with a population of 15 or 16 million people in the malarious areas, with some 2 million cases and possibly 18 or 20 thousand deaths a year, has a really serious problem. And Mexico is probably the country of the Americas which has least profited from the discovery of DDT and the residual insecticides.

Just during the past week, there have been high level discussions regarding the situation in Mexico, and there is considerable probability of the financing and organization of a nation-wide campaign there.

The summary of the report that Dr. Carlos Alvarado of Argentina made a few months ago after visiting all of the Latin American areas for a reconnaissance of the problem of Malaria is quite interesting. In 1950, Dr. Alvarado had made a similar study for the Pan American Sanitary Bureau. His report for 1954 was not so optimistic as was the report of 1950. It was demonstrated quite clearly that the DDT resistance is not limited to the *Anopheles* mosquito but has also spread to certain ministers of Finance who have to furnish money for the malaria control programs. However, the analysis of the situation indicates that more than one-half of the job is being done that needs to be done for the complete eradication of Malaria in the Americas.

It is not only in the Americas that there is talk of the eradication of Malaria, but the World Health Organization in other regions is stimulating the same type program that is being planned for the Americas.

This job is not going to be an easy one. Those who know the conditions under which Malaria occurs throughout tropical America realize the size of this tremendous task. It requires vision; it requires administration; and it requires money in considerable quantities. In some cases the money required will have to be considered as capital investment to be liquidated over a much longer period of time than the campaign itself requires.

The Pan American Sanitary Bureau and the World Health Organization both need the support of this Association and the members of the Association, not only for such things as the eradication of malaria and of *aegypti,* but also for other functions such as international organizations, part of the general world movement of better international understanding. In the field of health there is the possibility of coordinating activities on an understanding basis which is not so easy for workers from other fields. Those of you who were here this morning heard Mr. Mulrennan's appeal for concerted action with regard to our mosquito programs. It is even more important that we have concerted action, based on understanding by the health workers in the Americas, in support of the World Health Organization and of the Pan American Sanitary Bureau and our international program.

I thank you, Mr. Chairman.

PROGRESS REPORT ON BIOLOGICAL CONTROL OF *AEDES ALBOPICTUS* SKUSE IN HAWAII

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The control of *Aedes albopictus* presents difficulties where it breeds in areas of forest and jungle, beyond the range of routine premise inspection. An attempt to use biological control is being made in Hawaii on this tree hole and container breeder.

Three species of *Toxorhynchites* were tested for their suitability under local conditions. *Toxorhynichites brevipalpis* from South Africa and *T. splendens* from the Philippines bred well in the insectary. *T. hypoptes* from Panama was difficult to rear, and the laboratory colony of this species was discontinued.

Both *T. brevipalpis* and *T. splendens* were found to mate and to ovipost readily in cages. The larvae were reared to pupae in small individual streptomycin bottles. A culture of *Daphnia* was maintained to supply living food to the *Toxorhynchites* larvae. The pupae were gathered to permit emergence to take place with cages. The life cycle is completed in about one month. The female was found to be able to lay over 400 ova and to be able to survive for two months in the cage. The adults were fed on a diluted solution of corn syrup.

A stock colony of 10,000 *Toxorhynchites* is being kept in the insectary. The adults were kept for about five days in the cages after the time of emergence so that the females would be mated before being released. About 500 adults were kept in each square cage, measuring two feet each way.

The adults are being released in the valley and mountain forests where there are abundant tree holes and other available breeding places. An average of a thousand adults of each species has been released each month since March, 1954.

The site of release which was chosen was usually near the head of a valley. Batches of about 500 adults each were released from time to time until 10,000 have been released at each site.

Recoveries of immature stages and adults were made in two of the three valleys back of Honolulu in which the mosquitoes have been released. It is hoped that they can become established and be of benefit to our day mosquito control program.

Attempts to establish *Toxorhynchites* in four other islands of the territory are being carried out.

Requests for stock material have been received from various islands of the Pacific area. Living larvae have been sent to Tahiti, American Samoa, Niu Island, Guam, and Truk. Health officers of these islands are trying to introduce the *Toxorhynchites* in their territories as part of their mosquito control and anti-filariasis programs.

It is too early to evaluate the effectiveness of this project in biological control for *Aedes albopictus* in Hawaii.

It is a question as to how well the *T. brevipalpis* and *T. splendens* can establish themselves in nature under our local conditions and how widely they will spread from their sites of release.

EXPANDED GRASSLAND AGRICULTURE AND THE MOSQUITO PROBLEM

A. W. Lindquist, *Entomology Research Branch*
Agriculture Research Service,
U. S. Department of Agriculture

It is safe to say that most of this select group are acutely aware of some of the recent changes in agriculture. We know that an improved agriculture, including increased food production on the present available acres and bringing into production previously arid land, is necessary for the Nation's well-being and expanding population. Some of the changes in agriculture are creating problems which we as a group are striving hard to solve. We are concerned here with the immense expansion of grassland farming and its effect upon mosquito production and, indirectly, on the health of the people and their economy.

As we all know, for several years American farmers have been making a shift from row crops to grassland farming. By grassland farming is meant the planting and fertilization of improved varieties of grasses or legumes for hay crops or for use in grazing of livestock. Grassland farming is promoted and encouraged by Federal and State agencies, industry, and farm organizations. The objectives of this program, including soil building and increase of food for oncoming generations, with consequent greater profits for the farmer, are highly important to America.

When man changes his activities and environment, some natural changes usually result which operate to his disadvantage. As an example, insects in some way or another appear and cause trouble. Many of our most serious pests are native to our country, but were of little importance until we began cultivating the soil and planting certain crops. The wheat stem sawfly was not a serious pest until large acreages of spring wheat were planted in the Northern Great Plains. The chinch bug, the Colorado potato beetle, wireworms, several species of aphids, and many other insects became serious pests as the land was brought under cultivation. There has also been a great increase in mosquitoes in areas that have come under irrigation.

Mosquitoes have always been a problem in this country. The early settlers along the eastern seaboard suffered from their attacks. Until recent years, however, we were chiefly concerned with the mosquitoes that carry diseases such as malaria and yellow fever. Today these diseases are virtually nonexistent in this country; so we are becoming more aware of the importance of mosquitoes as economic pests, particularly as they affect man, livestock, and poultry. We are also concerned with their transmission of some diseases of man and animals, notably encephalitis.

Improved pastures and hay lands provide ideal conditions for mosquito breeding. Wet uncultivated soil is a preferred place for oviposition by many species of*Aedes* mosquitoes. The embryo usually develops within a few days and enters a state of diapause, which enables it to remain alive for months. In warm weather the eggs hatch almost immediately when flooded, and the larvae develop and emerge as adults in less than a week. Tillage as usually practiced on row crops may make the soil unfavorable for oviposition or destroy the *Aedes* eggs present, but on undisturbed pasture lands the eggs accumulate and survive for long periods. Furthermore, the micro fauna and flora found in water standing in grasslands serve as food for the larvae and provide a good environment for mosquito development.

In areas of heavy rainfall water accumulating in depressions on uneven pastures makes them excellent mosquito-breeding areas. In arid areas irrigation has created the same problem where none previously existed. In many pasture areas millions of mosquitoes are produced by each irrigation. For example, Husbands (1953) found that 13 broods of *Aedes nigromaculis* (Ludlow) developed in one season at Fresno, California. He also found that from 1 to 10 million larvae were produced per acre by a single flooding.

Cultivation of rice and cotton also contributes to the production of *Anopheles* and *Culex* mosquitoes. Other prolific breeding sources are vegetation-choked canals, drainage ditches, and tail-end water which cannot be diverted into a drainage system. Impounded water behind large dams and tens of thousands of farm ponds from coast to coast also are potential sources of mosquitoes and biting flies. A costly mosquito-control project was necessary when the TVA program of impounded water was initiated. These breeding problems arise solely from the use of water in agriculture and are therefore agricultural problems in the same sense as crop diseases and pests.

Associated with grassland farming is a large livestock population which provides more feeding opportunities for mosquitoes, and hence more of these insects. Improved irrigated pastures support more livestock per acre than non-irrigated grazing lands. The annoyance and torment to livestock by mosquitoes and the losses caused by these pests have been underestimated by farmers and livestock men. The farmer, his family, and employees are aware of the effect of mosquitoes on them, but seldom realize that mosquitoes reduce the weight gains and milk and egg production of livestock and poultry. Many farmers do not know that larger numbers of mosquitoes may attack animals at night than during the daylight hours. Livestock do not graze properly when fighting mosquitoes for long periods of time.

We have a few authentic records of mosquitoes killing livestock. Bishop (1933) obtained verification of the death of 80 cattle, 67 hogs, 3 horses, 1 mule, 20 chickens, and 2 dogs due to hordes of *Psorophora columbiae* (Dyer and Knab) near Miami, Florida. Since postmortem studies failed to reveal mosquitoes in the animal's air passages, it appeared that death was probably caused by loss of blood, although the toxins injected by the mosquitoes no doubt contributed to their death.

Mosquitoes transmit certain diseases of humans and animals, which take a heavy toll in sickness, loss of life, and economic costs. Encephalitis is endemic and therefore a constant threat in California and several parts of the United States. *Culex tarsalis* (Coq.), the most important vector of encephalitis, breeds in various situations, especially in older irrigated pasture lands that have settled and where ponds or depressions have formed. Husbands (1953) has shown that this species increases in abundance as irrigated pastures age. Its control is essential to reduce the incidence of encephalitis and is therefore of importance to all of us.

Let us examine for a minute the statistics on recent increases in the acreages under irrigation, taken from the 1950 Census of Agriculture (Table 1). We can assume that these increases reflect potential production of mosquitoes. In 1939 approximately 18 million acres were under irrigation in the United States. By 1949 this acreage has increased to nearly 26 million, or about 43 per cent. Approximately 94 per cent of these irrigated acres were in the 17 western states. Approximately 10 million acres, or 40 per cent of the total irrigated land, were in hay crops and pastures. Note that the hay crops exclude sorghum and annual legumes. It is likely that the 1955 Census of Agriculture will indicate about 15 million acres of irrigated pasture and hay crops.

Irrigation authorities state that Missouri's irrigated acreage has leaped 440 per cent in the last four years. Kansas has doubled the acres under irrigation during the last two years. This trend is moving forward throughout the Midwest. In 1952 California had approximately 1,200,000 acres of irrigated pastures, about 800,000 of which were improved. This represents an increase of approximately 70 per cent during the last 13 years.

Although not strictly grassland farming, rice culture is responsible for the production of enormous numbers of mosquitoes. It is not so well known that irrigated cotton fields also produce mosquitoes under some conditions. Rice is produced on 425,000 acres and cotton on 1,400,000 acres in California. Approximately 2 million people, including 100,000 farm families, in the central valleys are directly affected by these insects. The upswing of irrigation in California has been accompanied by an increase in the number of mosquito control districts of which there are now 50, expending a total of over 3 million dollars annually. Much of the efforts of the local districts is directed toward insecticidal control of mosquitoes on the lands of farmers who could have greatly reduced their production by better management of water.

In recent years the acreage devoted to improved pastures and haylands has increased enormously in the Southern and Southeastern States, where the moderate to high rainfall makes only supplemental irrigation necessary. In 1925 Georgia had only 900,000 acres in grassland crops, but by 1952 the acreage was 6,000,000. Significant increases in pasture lands have also occurred in other southern states. Mosquitoes can cause trouble on improved pastures when rainfall is heavy.

In my opinion many farmers, farm organizations, officials of irrigation districts, and State and Federal agricultural officials have not become aroused to the losses that mosquitoes are causing on grasslands. There are indications, however, that the importance of the problem is beginning to be recognized and more attention given to the relation between irrigation and mosquito production in areas where diseases are involved.

Important research on the ecology of mosquitoes in irrigation pastures is under way in California. Mr. Husbands and associates of the Bureau of Vector Control are studying the life history, habits, and development of various species on a 12-acre irrigated pasture near Fresno. The effect of the number of irrigations, spread and depth of water, settling of the land, vegetation, and grazing of livestock on mosquito populations is being studied on a continuous annual basis. Such studies should be expanded to cover different types of irrigated farming not only in California but in other states. The U. S. Public Health Service is conducting studies in irrigated pastures in Nebraska, Montana, and Utah, where diseases are carried by mosquitoes, but not on the other economic aspects of the mosquito problem.

A recent circular entitled "Mosquito Control on the Farm," by Bailey, Bohart, and Booher (1954), contains valuable information on mosquitoes and is well illustrated. If the farmers will follow the recommendations given in this circular, they will reduce mosquito trouble not only to themselves but to their neighbors.

In the simplest terms, control of mosquitoes is a matter of preventing standing water, but practical considerations often thwart control efforts. Even though land is carefully leveled and prepared for pasture or hay crops, some settling usually occurs, creating depressions which hold water and breed mosquitoes. Regardless of the care taken in preparing land for seeding, situations arise which cause water to stand. Cattle grazing in wet pastures compress the soil, thus making new depressions or increasing the size of old ones. Water accumulating in such depressions may breed mosquitoes in enormous numbers, but the farmer usually considers it impractical or uneconomical to plow and relevel his fields in the interest of mosquito control. Furthermore, he is generally unwilling, because of the cost, to use insecticides. This attitude is the rule rather than the exception in many of the irrigated areas in our western states. The only immediate remedy is a community control program.

Since research for farmers is usually conducted by governmental agencies, it is necessary to look toward these agencies for assistance and leadership in conducting investigational work. They should make three major moves: (1) Encourage the grower to use water in such a way as to prevent mosquito breeding; (2) disseminate through extension services information now available on mosquito control and urge its utilization where practicable; and (3) initiate broad research programs by entomologists, chemists, irrigation engineers, and land-use specialists. The entomologists should study the relationships of mosquitoes to the environment, including food, oviposition, and flight habits of the various species under different irrigation, soil, and crop conditions. These studies should be conducted with a view toward finding weak links in the biology of the mosquitoes whereby control can be facilitated. They should give special emphasis to control by means of insect diseases, predators, attractants, and traps, as well as insecticides. The entomologists, working with irrigation engineers, soil scientists, and others should study methods of preventing water from standing in fields and ditches. The research should include proper drainage, prevention of "sinking" of land and formation of pools, water-holding capacities of various soils, frequency of irrigation for any type of pasture or crop, early-spring or late-fall irrigation before mosquitoes become active, and relationship between good irrigation practices and best crop practices.

The Entomology Research Branch of the U. S. Department of Agriculture has been interested in expanding research on pasture-breeding mosquitoes for several years. Regular appropriations for this research are allotted only to the Corvallis, Oregon, laboratory. Only one full-time entomologist can be supported by the allotment; so you can see that the amount is not in keeping with the need for research. Our Orlando, Florida, laboratory, which operates on funds supplied by the Department of the Army, is carrying out important research on mosquito control as it pertains to the Armed Services, but except for the insecticide developments the results do not contribute much to the solution of farm mosquito problems.

During the past year the Soil and Water Conservation Research Branch of the Department has employed one man part time for a survey of irrigation and drainage practices in Montana and a second man for work on irrigation practices in relation to the mosquito problem in the central valley of California. This work needs to be expanded and coordinated with entomological and other lines of research.

Since mosquito control is of prime interest to the members of this Association, it behooves all of us to discuss at every opportunity with agricultural leaders and members of legislative bodies, at county, State, and National levels, the relationship of irrigation and mosquito production, pointing out the problems involved and the need to solve them. Given the facts, these leaders should recognize their importance to prosperity of the nation. It is then reasonable to expect that they will support the research we know should be done.

TABLE 1—*Acres of irrigated pastures and land in farms in 17 Western States.*[1]

	Irrigated land in farms Acres			*Acres of irrigated hay plus pasture, excluding sorghum and annual legumes*	
State	1949	1939	1939-49	1949	1939
Arizona	963,560	575,464	67.4	266,606	242,803
Calif.	6,438,324	4,276,554	50.5	2,003,073	1,469,604
Colo'do	2,872,348	2,467,548	16.4	1,607,935	1,405,209
Idaho	2,137,237	1,895,048	12.8	1,100,932	1,133,346
Kans.	138,686	82,872	67.3	20,025	19,365
Mont.	1,716,792	1,587,602	8.1	1,068,750	1,110,592
Neb.	876,259	473,775	85.0	135,080	109,223
Nevada	727,498	755,636	-3.7	666,396	714,809
N. Mex.	655,287	436,402	50.2	186,921	172,767
N. Dak.	35,294	19,975	76.7	8,104	7,550
Okla.	34,071	4,437	667.9	4,123	1,770
Oregon	1,306,810	1,030,228	26.8	834,346	793,392
S. Dak.	78,069	54,073	44.4	31,193	27,400
Texas	3,131,534	894,638	250.0	176,500	113,325
Utah	1,137,995	911,135	24.9	702,330	602,091
Wash.	589,035	493,982	19.2	266,883	266,627
Wyom.	1,431,767	1,284,027	11.5	1,041,265	992,041
Tot.	24,270,566	17,243,396	40.8	10,120,462	9,181,914
United States Tot.	25,787,455	17,982,830	43.4	—	—

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[1] **Figures obtained from the 1950 Census of Agriculture, Vol. 3, Irrigation of Agricultural Lands.**

TRENDS APPARENT IN VECTOR CONTROL[1]

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THE BROADENING CONCEPT OF VECTOR CONTROL

The same basic forces which have been responsible for the continuing evolution of concepts and practices in public health, including sanitation, have had a similar impact on vector control during the postwar period. Technologic advances, changes in problems, and the socioeconomic progress of the American People have all been prominent influences.

This trend has manifested itself in four distinct phases. The first phase is one of expanding scope of vector control in terms of program operation as exemplified by the five program elements which are administratively recognized by the Bureau of Vector Control, California Department of Public Health[2]. These are: (1) Mosquito and gnat control, (2) fly control, (3) rodent control, (4) ectoparasite and miscellaneous pest control, and (5) refuse storage, collection, and disposal.

The second phase is one of broadening socioeconomic purpose; an increasing awareness that discomfort and economic loss, as well as disease, in combination make up the case for man's control of vectors.

The third phase is a developing appreciation of the need for research, with special emphasis on "cradle to the grave" knowledge of the biology of vector and pest species and on the broad ecology of preventive measures themselves.

The fourth phase is the concept of prevention or source control, and the allied concept of conservation.

PREVENTION OR SOURCE CONTROL AND CONSERVATION

The prevention of vector problems by naturalistic measures has been a long-sought objective of vector researchers and of control workers serving as prospectors. The utopian objective of letting nature solve these problems following man's introduction of micro- or macro-predators or by encouraging the induced or natural alteration of food supply and shelter has a long history of failure as a cure-all. It also has met with partial success as evidenced for example by the value of larvivorous fish in highly selective situations and the shading of water to discourage sun-loving *Anopheles* larvae.

Those with an adequate understanding of the host-predator and food-shelter-population relationships fully appreciate that these natural forces work toward an equilibrium and hold forth little hope for broad scale biologic control methods of an enduring nature which would solve the whole problem. This does not, however, decry the significance of biologic methods as supplementary tools.

Of the present main interest is the prevention of vector problems by adjusting man's practices to avoid the conditions which give rise to them and the correction of existing problems by measures serving other economic purposes. This also has a historic background in global vector-borne disease control.

The impetus along these lines is largely concentrated in areas where man-made problems exceed, or potentially exceed, vector or pest production from natural sources. For example, the great expanses of salt marsh mosquito production areas which exist in such states as Florida, Louisiana, New Jersey, and Texas tend to limit interest in preventive activities as main objectives, even though minor benefits from work performed for other purposes can be cited. However, the expanding population and vigorous economic development of the United States are constantly increasing the extent and relative importance of man-made problems, while mushrooming suburban development tends to bring man into closer proximity to vectors of many types and from many sources. These same growth factors also tend to expand the list of opportunities for the correction of problems by "other-purpose" work.

Of primary interest in source reduction in irrigated areas is the application of conservation irrigation practices with mosquito control as an extra dividend over and above the other economic benefits resulting from this practice. Irrigation in arid and semi-arid areas is commonly responsible for most and sometimes for all standing water and mosquito production. The continuing expansion of irrigated acreages in these areas adds constantly and substantially to the problem. Elsewhere, the recent rapid growth of supplemental irrigation in the eastern humid states and the major expansion of irrigated rice acreages in the Mississippi Valley and Gulf Coast areas have created important mosquito production problems which may become far more significant and extensive in the future.

Those of you who know farmers, and especially speculative farmers, as many of you do, are well aware that utopia in water management practices on the farm will not be reached this year, or probably ever. The road to the goal of cooperative prevention or of permanent abatement is a long, hard pull, just as is any other sanitation accomplishment, be it urban, suburban, or rural in setting.

At the same time, it is unwise to sell agriculture short in view of the dynamic economic progress which is taking place each year in farm management practices. Cumulative accomplishments over a period of 10 to 20 years are little short of amazing. Prospects for success in conservation irrigation are primarily based not on the fact that mosquito reduction is obtained, but that the farmer's pocketbook is benefited, excepting of course that of the short-term speculative landrenter.

Moreover, where would we be today in sanitation if thirty or forty years ago the great difficulties which faced us in the promotion of better excreta disposal had led us to discard public and home sewerage systems in urban and rural areas as an infeasible objective, and we had perhaps concentrated instead on refining and promoting the box and con privy and the night soil scavenger system? The fact that many insanitary excreta disposal facilities still exist in this country doesn't detract from the great progress and benefits which have been realized from permanent sanitary facilities.

Although the case for conservation as one of the main methods of mosquito reduction is well-founded in California, the issue is even more clear cut in the irrigated areas of some other semi-arid states where people and taxable wealth are far more thinly distributed. The issue in California is to strengthen existing mosquito control pro-

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[1] This paper is an elaboration of one part of the Third Annual Report of the Committee on Vector Control, Engineering Section, American Public Health Association, 1954. Principal contributors to the part involved are listed as co-authors. The full committee membership includes Drs. George Bradley and F. E. Gartrell and Messrs. H. L. Fellton, W. E. Gilbertson, T. A. Olson, and F. H. Stutz.

[2] 1954. An Analysis of Vector Control. Bureau of Vector Control, Division of Environmental Sanitation, California Dept. of Public Health. Bulletin M-32. 3pp.

grams with a more economic and more effective armamentarium. Even those of you who carry on large scale chemical control may support and practice permanent source control in all its phases as a prerequisite to effective control of house flies at dairies and chicken ranches by basic sanitation, with supplemental chemical control measures.

The issue in many of these other areas is that there simply are no adequate economic or population bases on which to build organized local mosquito control programs. At the same time, there is need for checking the spread in extent of acute mosquito nuisance conditions and disease hazards arising from the mismanagement of water. Following the philosophy that half a loaf is better than none, the only tool which appears to offer promise is conservation irrigation, promoted by agriculture, carried out by the farmers themselves for multi-purpose benefit, and aided by the thinly spread services of mosquito prevention specialists.

Returning to the main theme, there are two common threads which tie together the various facets of the preventive-conservation concept. The first is the economic thread. Preventive measures are indicated because they not only are less expensive in the long run than corrective measures, i.e., conservation irrigation. Current interest in the composting of municipal refuse with ancillary fly control benefits is another example of a conservation measure which restores natural resources, accomplishes vector prevention, and at times may return a direct financial profit. The periodic fluctuation of water levels in artificial stream impoundments provides an excellent example of another type of preventive vector control which often may be performed without economic cost, or at least without added cost, when integrated into over-all water management plans.

The second thread is concerned with decentralization of responsibility along the characteristic lines followed by the public health movement in the United States. As long as vector control is carried on as a tactical attack, as exemplified by a mosquito abatement district with batteries of fogging machines, airplanes, and spray trucks, responsibility for all phases of vector prevention and abatement tends, in the public mind, to gravitate to the management of the vector control organization. A sense of responsibility for the prevention or permanent elimination of vector production on the part of private property owners maintaining public nuisances is anesthetized by the back-stopping activities of the mosquito-killers.

The concept of prevention is based on the approach that vectors are symptoms of environmental delinquencies and that the real place of vector control lies more in altering the cause than in dealing primarily with the effect and its specific aspects of suppression of immature or adult Arthropods. It is in complete harmony with the slogan "sanitation as a way of life," but has many overtones of its own. In accordance with this concept, the main role of the vector control organization would consist of technical and educational services in cooperation with other governmental agencies, private and public organization, industries (especially construction), and individuals (especially irrigation farmers) in guiding human endeavors involving water usage, housing, and population location.

Mosquito control is still the main activity of most organized local Vector Control Organizations. In the United States many of these organizations are entities which are independent of the local Health Department. Their annual budgets frequently may greatly exceed those of the local Health Departments. Integration with Public Health Agencies may occur in the State Health Department, as is the case in California, Florida, and Virginia, and varying degrees of liaison may take place with the local agencies.

The justification for this organizational segregation from the local Health Department is readily understandable where organized Vector Control Organizatons function as major public works departments using fire fighting tactics.

However, the trend in some areas toward shifting the emphasis from control of effect to control of cause, with concurrent veering away from direct operations by the Vector Control Organizaton toward an educational-persuasive-coordination-enforcement type of program, aligns it closely with the local Health Department in program pattern. It also tends toward reducing the magnitude of appropriations. At the same time, the decline of mosquito-borne diseases, rising standards of living, and enlarged concepts of public health, variously have led to the concept that Mosquito Control Agencies should concern themselves with all vectors. Interest in housefly control particularly has become prominent, and pressure for flea, louse, and other Arthropod control activities has appeared in particular localities. The establishment of a Bureau or Division of "Vector Control" in local Health Departments has been tried to meet the demand for an expanded control program, and there also has been a demand for local Mosquito Control Agencies to expand their operations to a full vector control program.

Under these circumstances, there is a strong case for the merger of Vector Control Organizations and local Health Departments into a single department, with advantage to both programs in many situations. Not the least of these would be the strengthening of sanitation programs in local health work by improvement in the caliber and size of staff and by the influx of new ideas and standards. For the most part, the field of sanitation lacks clear indices of levels of relative sanitation, particularly now that the communicable disease index is fleeting in many areas. The population levels of various vector species provide in many places a useful index of over-all community sanitation status. Conservation objectives might well be built into the Health Department Program, especially in the field of solid organic wastes.

Such integration of necessity can take place only gradually, and only where and when the broad socioeconomic ecology of vector problems encourages shifts in emphasis toward mixed preventive and permanent control principles. This marriage can succeed only through joint acceptance and adjustment. Local Health Departments and Mosquito Abatement Districts have a mutual responsibility to adjust their philosophies, tables of organization, and practices in the common interest.

The alternative is continued organizational separation. The highly specialized nuisance mosquito control district organization in an area where non-preventive measures are ecologically indicated might well continue as a separate organization. However, it would seem inadvisable on grounds of public policy for such districts to spread their wings over the entire field of vector control. Such agencies might expand their activities to include all insects with dominantly nuisance capabilities which require a specialized control effort and adversely affect the economy of the region. But the control of disease vectors is a responsibility of the local Health Department, and there are administrative and jurisdictional reasons against Mosquito Abatement Districts taking over Health Department functions, just as there would be against their taking over agricultural pest control functions. In many cases, an inter-agency contract, by which the Mosquito Abatement Agency does specified operations for the local Health Department, and vice versa, would appear to be a logical arrangement, and would avoid duplication of personnel, functions, equipment, and operations.

THE UNITED STATES' PARTICIPATION IN INTERNATIONAL MALARIA CONTROL PROGRAMS

Donald R. Johnson[1]

ABSTRACT

During World War II, the United States began giving various nations real assistance in malaria control campaigns. At present the United States is assisting malaria control programs in many countries through two principal channels: namely, United Nations and its agencies, and the Foreign Operations Administration.

The United Nations agencies to which the United States contributes include the World Health Organization, United Nations Children's Fund, and United Nations' Technical Assistance. These agencies furnish technicians and supplies for malaria control programs in many countries of the world.

The Foreign Operations Administration is the U. S. agency charged with administering all United States foreign aid programs and at present is providing malaria control assistance including technicians and necessary commodities to many economically underdeveloped countries of the free world. At present the major programs and the number of persons protected are as follows:

India	110,000,000
Indo-China*	3,000,000
Indonesia	3,000,000
Iran	4,000,000
Liberia	53,000
Nepal	300,000
Pakistan	8,000,000
Philippines	6,300,000
Taiwan	5,500,000
Thailand	4,500,000
Total	144,653,000

* Associated States of Cambodia, Laos, and Vietnam.

Some of the highlights of the 1954 control programs are as follows:

(1.) In India more than 110,000,000 people are now receiving protection against malaria in the world's greatest residual house spraying program. The United States supplied India in 1954 with more than 14,000,000 pounds of DDT 75% wettable powder for control purposes. Including India, the number of persons now protected against malaria in the major programs receiving direct United States aid is estimated to be 144,653,000. FOA provided approximately 22,000,000 pounds of DDT 75% wettable powder for these programs.

(2.) Further studies of *Anopheles* resistance to DDT were made. In Indonesia *Anopheles sundaicus* apparently has acquired high physiological resistance in the adult stage in two areas of Java. Dieldrin is at present controlling this species in the areas where resistance is present.

(3.) "Operation Mercy," an emergency flood relief mission to East Pakistan, demonstrated the ability of the United States to institute emergency malaria control measures in remote areas of the world within several days of receiving an appeal for help.

(4.) Specifications for insecticides and spraying equipment used in the programs were greatly improved thereby raising world-wide standards for these commodities insofar as malaria control is concerned.

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INDIA'S NATIONAL MALARIA CONTROL PROGRAM
A TWO YEAR PROGRESS REPORT

Fred W. Knipe

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India has embarked upon a program to reduce and gradually to eliminate its greatest public health enemy, malaria. This is a huge undertaking. India is a tropical country covering 1,221,072 square miles, and the greater part of its area varies from mildly to intensely malarious.

India's rainfall in general may be considered medium, averaging for a vast portion of the country from 30 to 40 inches annually; but it varies from less than 10 to more than 200 inches. Practically all the rain comes during the short monsoon season, often accompanied by violently heavy storms which leave behind immense flooded areas. In the resultant large and small collections of water, mosquitoes develop abundantly.

But monsoons alone are not responsible for India's malaria problem. In a generally dry country where rainfall is seasonal and heavy, some means must be found to conserve water for agriculture, for industry, and for power development during the non-monsoon months. For centuries farmers have carried on the practice of collecting run-off water in huge pools called "tanks," which are often as large as small lakes. These frequently become mosquito development pockets which may resemble marshes. However, in one respect India is fortunate in that permanent swamps, so often the source of mosquitoes in other countries, are rarely found.

There are other more sinister sources of mosquitoes. These are closely related to the agricultural and industrial progress of the country, notably the impoundment reservoirs where water is stored for irrigation and for power development. These impoundments in themselves are not highly potential development areas, since most native anophelines seem to shun deep water. But water from the impoundments flows onward, generating power, irrigating vast areas throughout the year, and all too frequently bringing about malariogenic conditions.

In the past the construction of an irrigation network was often accompanied by an enormous increase in the mosquito population. This was due almost entirely to faulty construction methods in the distribution system, where vast expanses of what has become known as "untidy water" were created—water which is a paradise for mosquitoes. Often the hazards of malaria resulting from irrigation systems were as great as the benefits derived from them. Railway and highway construction activities must share some of the responsibility for creating mosquito breeding places, since these public works improvements also have created untidy water.

Fortunately, during recent years this situation has been improving. Public works engineers have become more public health minded, with the result that in newer projects attention is being given to the avoidance of untidy water. Many projects, such as the vast Damodar Valley Corporation Development, have qualified malariologists as staff members. Most of them received their training at the Malaria Institute of India where training programs in public health have been carried on for years.

Only recently far-reaching agreements on procedures for building multipurpose public works projects in a way that would eliminate malarial conditions, have been approved by an appointed Coordinating Committee of Irrigation and Power Development Engineers and members of the Malaria Institute. This is considered a very important advance toward the control of man-made mosquito breeding areas throughout the country. India has had a long epidemic and endemic malaria history, beginning no one knows when, as is the case with disease histories everywhere. Until recently, the number of cases has been approximately one hundred million per year. An estimated one million of these died directly from the disease and a similar number succumbed from indirect effects. This was indeed a high proportion of the total annual death rate for the entire country and represented about 20 per cent of those deaths reported as being caused by "fevers."

Within this vast country, the number of deaths from malaria varies greatly from one section to another. The hyper-endemic and endemic regions are represented by Uttar Pradesh, Bihar, Bengal, Madhya Pradesh, Orissa, Bombay, and Madras. Because of their preference for foothill water, of fresh running streams, the mosquitoes *A. fluviatilis* and *A. minimus* predominate in these areas, causing severe cases of malaria throughout the year.

Territories representing moderate endemicity include the Indo-Gangetic delta, the Punjab, and Mysore. These areas, in which malaria is more often of post-monsoon origin ,are subject to periodic epidemics of mild to severe proportions, in which *A. culicifacies* is the predominating vector.

A. philippinensis is the principal vector in West Bengal. In this area malaria has been on the increase in recent years, probably because of the untidy water left behind by such modern improvements as new roads, railroads, and vastly extended irrigation systems.

The vector *A. stephensi* predominates in certain areas along the West Coast, but these areas are limited and of moderate endemicity.

A. culicifacies is by far the most widespread vector and unquestionably transmits the most malaria. *A. fluviatilis* is perhaps the next, and causes the most intensive epidemic malaria; dissections of *A. fluviatilis* show that sometimes as many as 26.3 per cent of these mosquitoes are carriers. *A. minimus, A. stephensi, A. philippinensis, and A. sundaicus* follow, probably in that order. *A. sundaicus* is particularly troublesome in the Andaman Islands.

The ravages of disease attributable to these mosquitoes is almost incalculable. Sinton in 1935 estimated that the financial loss alone was more than three billion dollars yearly, without considering other losses such as human debility and death. This tremendous burden was recognized as a foremost obstacle to advancement in practically every walk of Indian life, particularly agricultural development, up to the time of the conception of the National Malaria Control Program in 1953. Early in this program, it was estimated that 30 million persons were being protected against malaria in the country and that another 170 million required protection.

Previous attempts at control measures, beginning in 1845, led gradually to the use of DDT in 1944 by the armed forces in India, and since then the utilization of synthetic insecticides has been on the increase. Very little larvicide and Pyrethrum, once in widespread use, is employed today. During recent years close watch has been maintained for the possible development of Anopheles tolerance to DDT, but no such resistance has been recorded.

The problem of nation-wide malaria control in India has been established as an enormous task in public health, one which requires large outlays of capital, supplies, and equipment. Control of this disease could very reasonably be considered one of the building stones in India's Five Development Program. An opportunity to develop such an undertaking presented itself when the Point Four Indo-American Aid Program became effective. The first suggestion that such a plan be established was made by Dr. R. B. Watson of The Rockefeller Foundation, who had consulted with and secured the approval of Drs. B. A. Rao of Mysore and D. K. Viswanathan of Bombay, both old hands in the game of malaria control in the country. The summarized opinion of these three interested parties was presented to the then American ambassador, Chester Bowles, who in turn consulted with the government Ministry of Health. The outcome was that the Ministry of Health submitted a comprehensive program, ably drafted by Colonel Jaswant Singh of the Malaria Institute, and recommended as a project by the Coordinating Committee for consideration by the Planning Commission. It was finally established as a program and approved as a Point Four Project by U. S. Public Health officials acting as consultants to the Government of India. Thus the way was cleared for undertaking one of the largest malaria programs ever visualized, a program to free 200 million people from a disease which held them, and for generations had held their forefathers, in bondage.

The program was ratified in December 1952, and the first year effort was planned to protect 75 million people. This was the year 1953-54.

The plan envisioned—and I quote—a continuing program consisting of:

"1. An immediate 'operational' period extending three years to provide protection to about 125 million people.
2. A maintenance program for future years, continuing indefinitely, requiring alert watchfulness and continued control operations reduced in scale, if necessary."

The operational program as originally presented consisted, in summary, of the following essential features: (I extract in somewhat condensed form).

a. Coordinating all existing malaria control activities into the National Malaria Control Program.
b. Strengthening existing control programs and establishing new program in all states.
c. Expanding the staff of the Malaria Institute of India to provide over-all direction and to extend training facilities.
d. Providing malaria engineering consultations and other services for irrigation and hydro-electric projects.

e. Establishing an operational program based on residual spraying on insecticides to protect 125 million people, and treating malaria patients to reduce reservoirs of infection.

f. Constructing a second DDT plant in addition to the unit being set up by the Government of India through World Health Organization-United Nations International Children's Emergency Fund assistance.

g. Providing periodic evaluation of results.

A program of this magnitude cannot be set in motion in its entirety immediately. Therefore a progressive implementation was established, which would place in operation the 125 units, each to protect 1,000,000 persons, on the following time schedule:

1953-54—Implementation of .... 90 units
1954-55— " " an additional 35 units
1955-56—Continued operation of .... 125 units

Administrative and executive personnel to operate each unit consists of one medical officer and eight malaria inspectors. The permanent subordinate staff consists of 33 persons and the necessary seasonal field staff of 130 workers.

Spraying equipment assigned to each unit consists of 30 hand compression sprayers, 60 stirrup pumps, and one power sprayer. Since this equipment was not readily available in India, the greater portion of it has been imported during the first two years of operation. But makers of such equipment in India have now increased their facilities and improved their product to the point where further importations will be unnecessary.

At the time the plan became effective, no synthetic insecticide was being manufactured in India. This meant importation of the entire quantity, and during the first year 4,000 long tons of 75 per cent water wettable DDT were procured in this way. During the second year 6,670 long tons of 75 per cent water wettable DDT powder were scheduled for importation.

Although DDT is the insecticide furnished by the central agency, it is not the only one used in the program. Certain states have purchased small quantities of other insecticides, mainly Benzene Hexachloride, in an effort to push ahead with their work.

Since no synthetic insecticides were being manufactured within the country, and since foreign sources of supply entailed long distance shipping, it was decided to erect at least one, and perhaps two, fabricating plants. The first of these was established in Delhi and was scheduled to come into production in December 1954. Initially the producing capacity was 750 tons annually, but provision was made to expand as required to 1,500 tons. This expansion is now taking place, and by another year the maximum capacity may be attained. The second fabricating plant has not been started as yet.

This initial plant obviously cannot supply enough insecticide to carry on the control program, which means that India must continue to import insecticide for some time to come.

Water suspendable powder is the form in which the DDT is applied, and the standard rate of application is 100 mg per square foot of surface area. This is not a hard and fast rule but depends upon local conditions. Local conditions in turn very often depend upon the prevalence or severity of the monsoon in any specific area. Furthermore, application depends somewhat upon the number of spraying rounds which will be applied. In most areas, the number of rounds is two or three, and in these localities the standard rate of application generally prevails. But if four rounds per year are applied, as happens in a few areas, then the rate may be reduced to 60 mg per square foot per round. On the other hand, a few areas are so located that one round per year may be sufficient. In these areas as much as 200 mg per round may be applied.

Since the main objective of the residual spray program is to destroy infected or potentially infected mosquitoes, special stress is laid on intensive training in spraying methods for personnel. Frequent courses for malaria inspectors are given at the Malaria Institute where these men are trained in all phases of malaria transmission and control. Particular emphasis is placed on familiarizing them with proper techniques. They learn proper mixing procedures as well as proper care and maintenance of equipment. But above all, they are trained day after day, under practical conditions, in methods of applying residual spray to the vital resting places of mosquitoes and in lethal quantities.

These men return to their respective states where they train their own field personnel. As frequently as possible, visits are made by Malaria Institute personnel to these states, and the home state squads are watched in action and their errors in technique corrected.

While heavy emphasis is placed on vector destruction, the need for prophylaxis within the human population is not overlooked. All reported cases of malaria within the area must be treated in order to destroy the reservoir of infection. Qualified personnel, largely trained at the Institute, carry on this work. Resochin is being used for this important part of the program. Over one million cases were given treatment during the first year of the program. Figures are not yet available for the second year.

As might be expected in a project of this magnitude, everything has not always progressed as planned. There have been delays. It required time for the states to establish their organizations. Initial supplies of insecticide and of spraying equipment were late in arriving. Some of the suspendable powder apparently was not of the proper quality and had to be locally improved in suspendability by addition of wetting agents. Some of the imported equipment did not measure up to the standards expected, being subject to breakdown under severe field use. This was particularly true with reference to stirrup pumps. On the other hand, the compression sprayers were of good quality and have stood up well.

As might be anticipated, the greatest difficulty experienced with equipment was lack of sufficient quantities of spare parts. Since these are not readily available, and since it is always difficult to anticipate parts requirements, slight delays have resulted from this shortage.

Delays which have occurred must be considered as growing pains to which all such projects are subject. The program *has* gone forward almost on schedule. Hold-over delays from the first year have steadily been overcome during the second year, and the prospects for bringing the job to a successful conclusion appear to be excellent.

This does not mean that malaria will be eradicated from India in three years nor in five years. There are areas in the mountains which are almost inaccessible, inhabited by hill tribes who rarely emerge from their secluded homes. These people must be sought out and protected. In fact, it is sometimes said that these hill tribes are the real reservoir of the malaria parasite; if they could be freed from the parasite, the remainder of the program would be much simpler to complete. Whether or not this is true, it still is obvious that these people must be protected—an undertaking which will require time.

Real progress has been and will continue to be noted on the plains and in the more readily accessible areas where statistics for the first year of operation indicate most favorable results. Reports from widely scattered states agree that good progress in lowering the malaria incidence is being made. There is every reason to anticipate the continuance of this progress, and if it does continue, then by the end of the initial three years of the National Malaria Control Program, practically all of the malarious areas of India will be receiving protection. Those who know the potentialities of synthetic insecticides, such as DDT, and the energy with which the plan is being pushed forward, harbor no doubt that the program will be eminently successful, and within comparatively few years.

MILITARY USE OF CHEMICALS FOR MOSQUITO CONTROL

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Use of chemicals in the Army program of mosquito control falls into two main sectors, each of which is itself divided into two parts. The two major categories are, of course, indoor and outdoor control, of which indoor is composed of residual and space spraying and outdoor of larviciding and adulticiding. Starting at the center of the army area, in the quarters of the individual, whether it be a family unit in the Zone of the Interior or a row of tents in a Communication Zone or forward area, residual sprays of 5% DDT in a light grade petroleum solvent such as kerosene, are applied to all wall surfaces, screened openings, and the undersides of furniture, etc., at a rate of 1 quart to 250 square feet. Space sprays and fogs, produced by equipment ranging from individual aerosol bombs and flit guns to truck-mounted power machines, may be utilized as needed to kill adult mosquitoes entering through doorways and still unaffected by the residuals on the room surfaces.

In the area immediately surrounding these buildings, usually called the cantonment, sprays are applied each week to rain gutters, drains, pools collecting under buildings, and such artificially-constructed water sites, whenever survey shows that larvae in them have reached the third instar. Naturally none of these places is treated chemically unless all other means of elimination or control either have failed to achieve success or are initially infeasible.

Moving further outward, all areas immediately surrounding the cantonment area, if they are under military control or can be treated by agreement with the owner, and if they are not otherwise the responsibility of the local public sanitation services, are treated with larvicides weekly or whenever survey shows breeding of mosquitoes to the larger instars. This larviciding is done either by means of the two-gallon compression sprayers used for residual treatment, or by power equipment such as mist blowers, dusters, or by aircraft equipped with these. The area so treated is attacked concentrically as time, manpower, and materials permit, the first quarter-mile radius being considered the most important and each succeeding quarter mile the next most important in descending order. Aircraft, being unsuitable for treatment of breeding in, under, and around buildings are not normally employed over cantonment areas, though they may give them a pass while treating closely surrounding marshes; aircraft also are not utilized over dense vegetation, where sprays will not penetrate, unless there are special provisions which we shall discuss later.

Control of adults is effected temporarily by the use of fogs, and for longer periods by means of residual dust and spray barriers which are applied around the zones to be protected. This is done each week or at longer intervals when indicated by adult trap or resting counts made during the weekly surveys. These methods are varied to suit the local need as it is judged by the supervisor. Sprays and dusts which are applied primarily as larvicides are drifted over the nearby vegetation in the breeding sites. Dusts are also distributed onto shrubbery and vegetation within and surrounding the military area, and are allowed to settle on and in animal shelters, tool sheds, and similar buildings and their eaves, especially those that are roofed with thatch or hand-cut shakes. For this purpose 10 per cent DDT in pyrophillite, wettable DDT, or wettable dieldrin (as dry powders) may be used, applied by hand-operated or gasoline engine driven fan blowers. Sometimes, sprays and dusts are applied as residuals to the walls and the undersides of the roofs of animal shelters, latrines, and covered septic pits in farm areas contiguous to the army installations. Often it has been found that control of a relatively few such resting stations will very materially reduce the immigration of mosquito adults. Fogs are used where there are to be outdoor gatherings or where winds and other conditions bring adults from uncontrolled areas through the barrier zones with their ardor for biting still unabated.

To pass now from the general to the particular, let me describe our use of the foregoing methods in certain individual instances:

PHILIPPINES: Immediately after the war, in and around Manila, two problems presented themselves, and may be taken as exemplifying the types of control faced in military operations. First there was the control of mosquitoes breeding in rubble, damaged buildings, and sanitary facilities which in normal times would have been well maintained and helpful, but which under existing conditions aggravated already bad situations. Secondly, there was the normal breeding occurring in natural sites which were far from the controlled areas of peacetime, where the military encampments and operations necessarily were placed in order to unencumber the civil situations. In the Philippines, these natural sites were streams and rice paddies. Although we had been told that *A. minimus flavirostris*, the malaria vector, did not breed in contaminated water or rest in houses, we mist-sprayed all streams and bordering vegetation, even in the barrio and city areas, and residually sprayed the interiors of all Army living quarters, theatres, and mess halls. Paddy areas around installations were dusted or, if disused, were sprayed by power equipment, and those too inaccessible or too numerous for easy ground spraying were treated by small liaison-type aircraft. Tests showed us that spray from aircraft did not penetrate heavy grasses well, although dusts did do so, leaving also a residue on the plants to affect the resting adults. For this reason, brush-grown streams were cleared only sufficiently to permit passage of the spray men and to free the drainage of the water and were then treated from the ground. Adult mosquitoes, particularly engorged females, were found in houses in the morning whenever control was relaxed or houses were left unsprayed, but even unscreened houses were found to be insect-free when treatments were applied on schedule. Interior treatments were therefore required at 60 day intervals. Fogging was tried both in war-damaged downtown areas and open rice field areas, inasmuch as fog was at that time being given credit for larvicidal efficacy. However, adult population counts invariably returned to the pre-treatment level within an hour after operations and, except for diplomatic uses or garden parties, the foggers were retired.

OKINAWA: In Okinawa, even more than in the mainland of Japan, rice paddies present a problem. Here *A. sinensis*, a paddy breeder, is an active carrier of malaria, which it is not in the Philippines, and the paddies are located not only in flat areas but up into the narrowest ravines. In some of the Ryukyus, where *A. minimus* is an additional vector, sericulture prevents use of airplanes to disperse insecticides, but on Okinawa itself aircraft are an important part of the control. Dusts were applied by helicopter here with exceptionally good effect, but the cost of the operation and the eventual limitation of these craft to air rescue work prevented the method from being made into a continuing routine. Pyrophillite and clay pellets and tobacco dusts have been recently used quite successfully in getting penetration in rice paddies late in the season when growth is heavy. These heavier particles have the advantage that they can be applied when the wind is too high for ordinary dusting, and they thus free the operator of being shackled by the weather. However, the pellets are presently too heavy to be distributed well by ground equipment. (Experiments at the Engineer Research and Development Laboratories and in semi-arctic tundra at Ft. Churchill, Canada, lead us to believe this difficulty can be overcome with power equipment if not with hand-operated rotary dusters. However, it will be most desirable if manufacturers of both clay pellets and vegetable granules, such as tobacco dust, can be induced to separate out material of not larger than 60 mesh.)

JAPAN: In Japan, concern for the protection of sericulture prohibits use of airplane spraying or dusting and restricts severely the usefulness of power equipment capable of too widespread or indiscriminate broadcast of chemicals. Foggers are used to some extent, particularly against adult mosquitoes in outdoor gatherings in city areas. Since so called "pest" mosquitoes which breed in gutters, cess-pools, tin cans and every other conceivable collections of water, are the transmitters of encephalitis, this serves an essential health purpose as well as preventing mosquitoes from spoiling otherwise pleasant functions. However, a more effective knockdown and kill has been secured in many areas by use of the wettable DDT powders and the pyrophillite or talc-based DDT dusts, applied dry by rotary or power dusters at rates of about one pound per acre. Residual mist sprays of DDT emulsion in water and even of kerosene solutions have also been utilized to good effect and without foliage burn where care was exercised. Primary control is, of course, by mists applied weekly by means of 2-gallon, hand-operated sprayers.

KOREA: Korea presented us with perhaps the best opportunity which could have been devised for testing the effectiveness of our chemical mosquito-control methods under conditions of great urgency and complete lack of permanency while also testing our equipment for its ruggedness and dependability. The equipment did not come through the test nearly so well as did our methods. Machines which seemed well designed and heavily built, broke down, corroded, and developed an insatiable appetite for unobtainable spare parts, although some of the simpler and seemingly less durable affairs kept operating like the Model T Ford on bailing wire and cussedness.

Because the situation was fluid and our tenure in any case was not expected to be long, we concentrated on chemical control to the exclusion of almost every other consideration save a foredoomed attempt at primary area sanitation. L-type aircraft, mist blowers, and small push-cart power dusters and foggers of Japanese design, were utilized; but the main job of chemical application was done with 2 and 3 gallon, compression type, pack sprayers. First attention was given to ditches, latrines, paddies, and empty cans thrown into the bushes and the barbed-wire "accordions." Residual sprays were applied to walls and under eaves wherever permanent-type facilities were occupied. Air sprays were applied to rice paddies, many of which are, as in Okinawa, in very narrow ravines in the multitudes of small, steep hills.

GERMANY: In the American occupation zone of Germany the unique breeding place for mosquitoes was in the watering barrels in the home gardens. These home gardens, like our "Victory Gardens," were small, individually-owned plots grouped together into larger, homogenous areas which might be vacant lots in town or more extensive tracts on the edge of the urban area. Each was surrounded by a fence, usually with a padlocked gate, and always there was a barrel in each garden for storing the rain water used in irrigating the growing vegetables. Since ingress to the locked plots was difficult or even impossible, DDT was distributed in small quantities to these urban farmers. This was also an effective means of controlling the mosquitoes breeding in the cement pits in which liquid composts, principally night-soil, were retained for bacterial digestion (I might add in this connection that handfuls of DDT similarly distributed in Ryukyuan villages and applied by means of handkerchiefs to the small individually-owned components of large paddy areas, also gave good control despite the primitive application method).

UNITED STATES: In the Zone of the Interior and such overseas zones as are normal components of the United States, permament drainage and filling were far advanced even on temporary posts before the advent of DDT. However, funds and labor for such activities as mosquito control are chronically short until a health emergency occurs, and it was therefore decided to supplement permanent control with thorough chemical applications. Chemicals are cheaper than labor in this country even when the chemicals are used widely. In the replacement of diesel oil applications by DDT mists, the new method was cheaper in both labor and purchase outlays than the old.

Applications were designed to be economical of material but to be heavy enough to get an optimum lethal dosage rather than a minimum one, and it was decided to be unstinting in regard to thoroughness of coverage. With the apparent elimination of malaria in the United States and the gradual reduction of funds and personnel allotments which has gone on steadily since 1945, the need to conserve has become greater and greater. Major engineering projects and spot applications based upon careful and continuing survey have had to be postponed. Under these circumstances, chemical control in a somewhat shot gun fashion, and aiming only at the known high spots or at places where complaints originate, has become the mainstay of the program.

The discussion of Army control of mosquitoes by chemical means would be incomplete, naturally, without any mention of resistance. The fact is that the Army has encountered no measurable resistance in mosquitoes in any area overseas or in the United States. There are three possible reasons for this: Most installations are away from heavy concentrations of salt water marsh populations; we have not practiced the widespread use of minimum lethal dosages that have been common elsewhere; and we have operated principally in areas where considerable untreated mosquito populations are ever-present just outside our control areas, and presumably come continually in to breed out any accumulating resistance. Whatever the explanation, no provable instance of resistance in mosquitoes has as yet occurred.

To sum up the Army's experience with chemical control: we have used it extensively in lieu of permanent sanitation measures, or to supplement them where lack of adequate manpower or funds makes permanent work incomplete. We have proceeded upon the theory that chemicals were cheaper than labor and should be used thoroughly though not heavily and have had excellent results in maintaining our areas relatively free of mosquitoes by this means. No resistance to DDT has been observed in demonstrable quantity.

SIGNIFICANT ADVANCEMENTS IN THE MOSQUITO CONTROL PROGRAM OF THE UNITED STATES NAVY

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Mosquito control in particular, and pest control in general, have made important advancements within the United States Navy during the last year. The establishment of a Navy Inter-departmental Pest Control Committee late in 1953 made its first contributions to the field during 1954. This high level organization provides for the most practical coordination of all pest control activity at command levels and expedites action on all pest control problems. The economy of this technique has been observed in the past. An integrated program has been developed and put into operation.

As the effects of this Committee brought emphasis to to control of pests throughout the Navy, the program was broadened to include the control of:

a. Disease vectors.
b. General nuisance and household pests.
c. Pests of stored products.
d. Wood destroying organisms.
e. Vegetative pests.

This broad coverage of pest problems increased the need for specially trained personnel. Training programs have been conducted in various Naval Districts with excellent results. Naval reserve training programs at the Preventive Medicine Unit No. 1, Naval Air Station, Jacksonville, Florida, and the Insect Vector Control, Naval Air Station, Alameda, California, have carried this special work into the reserve forces. Careful planning in the use and distribution of available specialist personnel has provided technical advice and supervisory assistance to all Naval establishments. The school for Environmental Sanitation Technicians, U. S. Naval Hospital, Oak Knoll, Oakland, California, has increased its training allowances and improved its facilities. The outlook for reduced property loss and improved health and morale by effective control of disease vectors and pests is most optimistic.

Since the close of hostilities of World War II and especially since the cessation of wide-scale activity in Korea, greater attention has been directed to the development of proper equipment for the dispersal of insecticides, testing of insecticides for military use, and planned permanent controls. The first two items will be reported in other papers which will be presented during these meetings. Permanent measures at naval establishment have been dependent on the future plans for the various establishments. As these plans become firm, the value of these permanent controls can be weighed. The results and recommendations of numerous pre-war surveys, enhanced by wartime controls, have made possible many permanent control programs. Some of these already are in operation, and others will begin this year. The importance of permanent controls has never been questioned, but could not receive appropriate evaluation until the location of permanent military establishments was known.

The cooperation of the military services and the coordination of their programs with the organized controls of cities, counties, and states has been of great mutual benefit. The American Mosquito Control Association has been a constant source of information and assistance, and is used as an example of this necessary and most valuable relationship. Since the problems within the Naval establishment are widespread and various, the understanding and expert assistance of the scientific societies, the United State Department of Agriculture, and the United States Public Health Service are invaluable. The results of their reported experiences and research are the bases for many developments which lead to the effective solution of many of our problems. From the specialists with our Medical Research Units and Laboratories, and the careful observations of our field operators, the successes and failures of widely used techniques can be assembled. These results have brought pest control in the Navy to a new high in efficiency and a new low in cost and personnel requirements.

The opinions expressed are those of the writer and are not to be construed as policy of the Navy Department.

EDITOR'S NOTE: Commander Hirst gave an illustrated talk on a source eliminaton problem at Casa Linda in lieu of the above paper at the Conference.

RECENT DEVELOPMENTS IN MOSQUITO CONTROL IN THE AIR FORCE

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In 1954, as in past years, the bulk of insect control work in the Air Force was directed toward the control of mosquito populations around the world. Disease transmitting mosquitoes were given primary consideration, but in many areas it was necessary to control pest mosquitoes where the morale and efficiency of personnel were affected.

The significant developments in mosquito control in the Air Force during 1954 may be divided into the following fields: operations, research and development, publications, and materiel.

OPERATIONS

The mosquito control program in the Air Force was divided into two phases: air and ground. One or both, depending upon the biological environment, were used to control populations within the vicinity of Air Force installations.

In the aerial phase the dissemination of both liquid sprays and impregnated granules was accomplished. Ground control consisted of temporary measures and permanent measures. Temporary control measures included the application of larvicides in infested waters; application of residual sprays in housing and mess areas; and control of adult mosquitoes in outdoor areas with fog and mist sprays. Permanent control measures utilized were: draining through ditching; filling in of breeding areas; and elimination of natural ecological habitats through burning or clearing.

Coverage of areas where the dissemination of insecticides by means of aircraft was considered a practicable supplementary mosquito control measure was accomplished throughout the United States by the USAF Special Aerial Spray Flight based at Langley Air Force Base, Virginia. In 1954 this unit serviced twenty-two different Army and Air Force installations ranging from Massachusetts to the tip of Florida and from Louisiana as far east as Grand Turk Island in the British West Indies.

This Flight, consisting of three C-47 and two L-20 type aircraft, sprayed a total of 148,286 gallons of insecticide over 369,304 acres during 1954 at an average cost of $0.115 per acre sprayed. This figure was based on the cost of total flying time plus per diem paid the aircrew members. Neither salaries nor the cost of the insecticides was considered in the computation.

The Special Spray Unit serviced bases in the Air Materiel Command, Air Research and Development Command, Strategic Air Command, and Tactical Air Command. Each of these major air commands has bases located along the Atlantic seaboard and in the southern states.

Ground control programs for the control of mosquitoes were operated in each of the major air commands within the United States. These are the Air Defense Command, Air Proving Ground, Continental Air Command, Military Air Transport Service, and the Air Training Command in addition to those listed above. The individual programs were handled at base level by personnel who had received formal training in this type of work.

Aerial spray was a major mosquito control measure in the Alaskan Air Command. No resistance to DDT was reported in the mosquitoes found in that region. Control of mosquitoes around the small Aircraft Control and Warning sites was attempted but not considered practicable. Screening was relied upon for protection instead. Collections of mosquitoes made from aircraft arriving at Alaskan air bases from Far Eastern stations incurred the initiation of an extensive disinsectization of aircraft program in this Command.

Control of *Anopheles albimanus* was the major feature in the mosquito control program in the Caribbean Air Command. Control was achieved through fogging of the base area each night. Control was temporary and had no effect on off-base areas. Drainage of those breeding areas adjacent to the Air Force installations was considered for 1955.

Possibly the most extensive mosquito control program in the Air Force was conducted within the Far East Air Forces Command. Aerial dissemination of liquid sprays was accomplished in the Philippine Islands, on Okinawa, and on Guam by means of T-6 aircraft modified with tanks suspended beneath either wing. In March 1954 assault exercises upon Iwo Jima Island were carried out by a Marine division. The island was sprayed with 20% DDT Airplane Spray Solution by aircraft prior to the invasion. A gratifying reduction in both the mosquitoes and other insect populations on this island followed the aerial spraying was considered to have justified the expense.

In Korea, the Fifth United States Air Force continued its program against the vectors of malaria and Japanese B. encephalitis. Twenty per cent DDT Aerial Spray Solution was still being used in that theater, and there was little change in the program as it was originally set up in 1951 and described at the joint AMCA-NJMEA meeting held in 1954. It was felt by the Office of the Surgeon General, United States Air Force, that the continued relatively low rates of both malaria and Japanese B. encephalitis in Air Force personnel in the Korean theater could be attributed in part at least to the aerial spray program.

In the Northeast Air Command, which has its headquarters in Newfoundland, Canada, aircraft were used to spray Sondrestrom Air Force Base on Greenland to control the pest mosquito population there.

Headquarters United States Air Force in Europe (USAFE) reported that the program for control of mosquitoes in that theater was not an extensive one. The major insect population faced by Air Force units in North Africa, England, and on the Continent was reported to have been the common housefly.

RESEARCH AND DEVELOPMENT

Research on three mosquito control R&D projects was accomplished in 1954. Two of these had to do with the disseminaton of impregnated granules.

In the summer of 1953, two L-20 DeHaviland Beaver aircraft were flown to Langley Air Force Base, Virginia, and assigned to the Special Spray Flight. These two aircraft were equipped with spray kits consisting of two 55-gallon drums lying horizontally on the cabin floor and a cylindrical venturi with an 8-inch diameter air intake orifice suspended beneath the belly of the aircraft. Flow of the insecticide was by means of gravity and the rate was controlled manually by a crew member who operated a rotary shut-off valve upon hand signals given by the pilot. Effective swath width of this apparatus was approximately 75 feet. The rate of flow was estimated on the ground after landing and the droplet sizes were variable and uncontrollable.

A third L-20 equipped with a commercial rotary brush spray kit was assigned to the Special Spray Flight at the same time. The swath width and droplet size were calibrated. The former was found to be 120 feet and the droplet size fairly consistent. This kit was efficient, but there was some trouble with the cut-off valves. The rubber seals contained within these valves expanded due to the action of the insecticide vehicle used. This expansion caused them to bulge far enough to be sheared off by the moving metal parts.

Due to the inefficiency of the venturi kit and the difficulty of the maintaining rotary brush parts, these original spray systems were replaced with boom spray kits developed along the principle of the equipment used on the C-47. At first the kit consisted of three 55-gallon drums standing upright in the cabin and inter-connected with hoses. The insecticide flowed from these tanks to a pair of electrically-driven B-26 vane fuel transfer pumps, which individually fed each of two booms. The booms were constructed of 1⅛ inch nominal diameter steel aircraft tubing and were supported by A-frame struts bolted to the lower surfaces of the wings. Ten ⅛ B-10 Spray Systems nozzles were attached on each side. The effective swath width of this kit was 140 feet. The pumps were controlled by the pilot through a master switch on the pilot's instrument panel and an on-off switch control on the wheel grip. The kit was considered quite efficient except for one thing: the pumps which maintained 30 PSI did not have capacity for increased flow. the atomization rate dropped in proportion to decreases in pressure. It was found that 14 nozzles produced a more consistent spray than all 20.

In 1954 this kit was modified by the replacement of the three 55-gallon drums with a rectangular stainless steel baffled tank with a capacity of 175 gallons. In addition, a verticle stand-pipe and an emergency dump valve were added. The emergency dump apparatus consisted of a spring-loaded valve attached to a large cap located in the belly of the aircraft and sealed in the bottom of the internal insecticide tank. The valve was cocked and ready for instantaneous release. It was operated manually by a cable which ran through the pilot's compartment. The size of the dump orifice coincided with that of the camera hatch on the belly of the aircraft, and a full load of insecticide could be discharged in a little less than 10 seconds. No change was made in either the insecticide discharge pumps or the booms.

Recognition in 1954 of the applicability of impregnated granules as a mosquito control measure instigated development of effective hoppers on aircraft so that these materials could be disseminated from the air. A stainless steel hopper of 1,000 granule pound capacity was built for the L-20 aircraft. This hopper is box-shaped, corresponds with the shape and size of the loading door, and is equal in width to the interior of the aircraft. It is inserted into the aircraft from the side, then the forward end is raised several inches and a wooden frame slid in between the hopper and the floor of the cabin in order to support it in a tilted position. Loading of the hopper is accomplished through a hatch located on the upper surface. The granules are poured through this opening by means of a feeder suspended above the aircraft.

The granules flow by means of gravity through an open slot which is as wide as the hopper and located along its base. The granules flow aft through a constricted and rectangular pipe which projects through the camera hatch and supports a venturi suspended below the fuselage. The rate of drop of the granules is controlled by a limit switch which controls a sliding cut-off valve located at the end of the rectangular pipe. Control of this valve in turn determines the cross section area of the opening in the top of the venturi box.

In September of 1954 the Air Force was invited to send a representative to the Canadian Defence Research Board Experimental Station at Ralston, Alberta, Canàda, to review work which had been accomplished in the development of equipment for the dissemination of insecticides by means of aircraft. A comprehensive report including a detailed description of a granular insecticide hopper developed for installation in a C-47 aircraft was submitted to the Air Force Surgeon General. If the principle of this hopper developed by the Canadian Defence Research Board is accepted, it will facilitate fulfilling the Air Force's requirement for modification of its own C-47 aircraft.

Several experimental flights to test the efficiency and practicability of the dispersion of granular insecticides on Air Force bases were accomplished in 1954. In August the Special Spray Flight dispersed insecticide granules over Patrick Air Force Base in Florida. The dispersal equipment used was that described above for the L-20 aircraft. The insecticidal material was 1% benzine hexachloride impregnated in a 30/60 mesh, granular carrier, composed of 75% bentonite and 25% attaclay. Ten thousand pounds of this material were placed in marsh and swamp areas. The rate of application was 23 pounds to the acre. Penetration of vegetation in each area was excellent. Qualitative results were good, and the larval control rate appeared to be superior to the liquid spray.

Again in August this same aircraft was utilized to disperse granular aldrin on Robins Air Force Base, Georgia. While the final results of this spray are unknown, the interim results were reported to have been most favorable. Difficulties incurred in both experiments were the small payload of the DeHaviland Beaver and the relatively narrow swath width.

PUBLICATIONS

Since the bulk of the Air Force work in insect control was directed against mosquitoes, we might consider most Air Force arthropod control publications as being primarily mosquito control publications. Air Force Regulation 90-3, Insect Control by Aircraft, was brought up to date in May, 1954. A revision of Air Force Regulation 90-2, Insect and Rodent Control ,is being processed through Headquarters USAF at this time. A Tri-Service Technical Manual ,to be designated as Air Force Manual 85-7, Insect and Rodent Control, is undergoing preparation. The better part of this manual has already been written, and the sections on mosquitoes and their control are comprehensive.

In October, 1954, the first of two volumes comprising Air Force Manual 160-5, Flight Surgeon's Manual, was published. Chapters on insects, insect-transmitted diseases, and insect control are included in the Preventive Medicine Section which will be published in Volume 2 during 1955.

Table of Organization 1-4101, which contains authorized preventive medicine cellular units, was revised in 1954. The number of individual units was increased, and more positions than had previously been allotted were established for Medical Entomologists.

Insect and rodent control on an Air Force installation is a bi-lateral activity. Air Installations (engineers) is responsible for the supervision and execution of control measures. The Base Surgeon cooperates in this work by conducting surveys, investigating the prevalence and distribution of disease-transmitting arthropods, and maintaining technical surveillance of the program administered by the Air Installations Officer. In order to supplement this program in Tactical Air Command, both the Office of the Surgeon and Command Air Installations published guides. The Tactical Air Command Preventive Medicine Guide, originally published in June, 1952, was revised in May, 1954. To aid the Preventive Medicine Technician to fulfill his responsibilities in insect and rodent control work at installation level, Tactical Air Command Preventive Medicine Technician's Guide was published in September, 1954. Both of these publications are comprehensive and excellent preventive medicine guides. In November, 1954, Command Air Installations published Tactical Air Command Insect and Rodent Control Guide for use by Air Installations personnel at installation level who are responsible for conducting the base insect and rodent control program.

MATERIEL

Procurement of insecticides, rodenticides, and insect and rodent control equipment is a responsibility of Air Installations. This is in accord with its requirements for the execution of insect and rodent control work at installation level.

Table of Allowances Number 1-1C, Installation Engineer Equipment, dated 10 June, 1954, prescribes the allowances considered as the maximum equipment normally required by installation engineer functions at Air Force installations world-wide. This Table of Allowances may be supplemented by a Base Authorization List consisting of either standard materiel items available through normal USAF supply channels or non-standard items considered necessary due to environmental or abnormal conditions.

Standard pesticides and control equipment are listed in the USAF Supply Catalog under Classes 24 and 39C. Instructions for the procurement of non-standard supply items are supplied by Headquarters USAF.

Air Force Procurement Instruction Number 70-50, Insecticides and Pest Control Items, dated 1 October, 1953, lists 72 insecticides and rodenticides authorized for local purchase by Air Force installations. Only a few of these are listed in the USAF Supply Catalog.

One commercially-produced insecticide and one item of disseminating equipment were added to the list of centrally procured items to be included in the USAF Supply Catalog during 1954. These were: Insecticide, dieldrin, emulsifiable concentrate, 18% technical dieldrin by weight and the Dyna-Fog Jet Fog Generator with an operational nomenclature comparable to that of the TIFA.

An Equipment Component List for an individual portable kit to be issued to Medical Entomologists on active duty in the Air Force has been approved by Headquarters USAF. This kit includes collecting, preparing, and mounting equipment (including a dissecting microscope) and was designed to provide officers with the minimum laboratory items required to conduct adequate entomological surveys, prepare, mount, and examine microscopic material.

Mosquitoes, flies, and lice are the ranking arthropod vectors of disease creating a hazard to the health, welfare, and morale of Air Force personnel throughout the world. While the control of mosquitoes alone is not conducted as an individual program in the Air Force, but rather as a phase of the over-all Insect and Rodent Control Program, control of these animals is considered to be of paramount importance by the Air Force Surgeon General.

The Office of the Surgeon General has either initiated or become involved in a majority of the developments enumerated above in accordance with this thinking. The Surgeon General is acutely interested in the progress of work in preventive medicine, and it is his intention that steps will be taken to insure a continuation of developments in mosquito control so as to both improve the living environment and provide an effective entomological service with the Preventive Medicine Program of the United State Air Force.

THIRD SESSION

9:30 A.M., TUESDAY, JANUARY 25, 1955

UNIVERSITY OF CALIFORNIA, LOS ANGELES

The meeting was called to order by President-Elect Richard F. Peters of the American Mosquito Control Association and the Bureau of Vector Control, California State Department of Public Health.

Mr. Peters: You will note that my hair is all here, therefore I couldn't be Donald Grant, but, inasmuch as he hasn't shown up, I have been prevailed upon to act as the opening agent to the Encephalitis sessions to be presented here at the University of California. We welcome you here to the second day conference. Are there any special announcements that should be made?

I would like to make one with respect to the Motorcade. We have had a moderate sign-up this far, and I would like to urge all of you to plan to take the motorcade following this conference. Since it is going in three directions, please contact me personally. I have a sign-up list that you may put your names on as to whether you have a car and which route you want to see.

The next job I have particular pleasure in because the welcoming speaker used to be my boss. Dr. Halverson is undoubtedly identified with the growth and development and the bringing of the State Department of Public Health of California into full manhood from a program that was slightly smaller and slightly less modern and complete. So, Dr. Halverson, in your new duties here at the University of California at Los Angeles in the Medical School and Public Health, we know that you still are a practitioner of public health in full. We welcome you to welcome us.—Applause.

Dr. Halverson: Mr. Chairman, honored guests and members of the conference: On behalf of Chancellor Allen it is a great pleasure for me to welcome you to this building and to this meeting and to throw open to you all the facilities and interests that the University may have for you. We are very happy that you are here and I'm personally honored in making these few remarks, particularly because this meeting is dedicated to a man who has gone through the hard parts of the early stages of the development of the programs in which you are so interested—Mr. Gray.

Now I say I'm pleased to do this because you don't only go about destroying mosquitoes more or less like the simple fashion that was proposed by a clever advertiser who advertised a sure death for potato bugs for $1.00. When the $1.00 went to him, and when this efficacious remedy came back, it was two blocks of wood with instruction to put the potato bug on one block and hit it with the other.

You are doing that with these arthropods. You are using every facility that is known to you at the the present time. That's your pedestrian, every day job. You are doing more than that. You are keeping your eyes open. You are curious about why mosquitoes thrive in certain rice fields when everything is done to knock them out. Why don't they thrive in other rice fields where practically nothing is done?

You are interested in finding the cause; in other words, you are interested in developing more information about the ecology of this arthropod. I was reading to one of my adopted grandsons last night and called mosquitoes, "bugs." You are interested in their eradication, but more importantly in doing everything you can to learn more about the life habits of these arthropods—how they disseminate disease; what conditions do they live best under; and, of course, how best they can be done away with at the least expense.

For this reason, I am very happy to have been a part of your organization, to have a part in the work with you, and particularly to welcome you this morning to this session. I thank you.

Mr. Peters: Thank you, Dr. Halverson. Your remarks certainly indicate that you are putting across a profound ecological approach to this problem. I have tried to stress that in my past discussions with my former Director, and I am pleased to see that he had a slight tendency to agree.

This morning we are going to have a symposium to be moderated by Dr. K. F. Meyer, our esteemed authority on this subject, who has been for a number of years in California.

Dr. Meyer, would you care to have your panel of experts up before the group so we may look at them during the course of this period? If so, we are ready for you. All right, Dr. Meyer has given me the authority to order you up here.

Dr. Meyer: Members of the Associations, and Ladies and Gentlemen: You will probably grant me the privilege of a few introductory remarks before we start the symposium.

SYMPOSIUM: ARTHROPOD-BORNE ENCEPHALITIDES

Chairman:
Karl F. Meyer, M.D.
Hooper Foundation, University of California, San Francisco

Since epidemiologic, and later experimental, evidence provided proof that arthropods are concerned, and quite vitally, in the transmission of the agents of disease (of the filarial worm causing elephantiasis in man; of the protozoan parasite causing malaria; the cattle diseases Texas fever and nagana; of the viral agents of yellow fever, dengue and certain encephalitides) the medical entomologist has assumed a key position not extant even 50 years ago. Not only as an investigator at the laboratory bench, but more significantly as an observer in the field, the entomologist and the sanitary engineer have been influential in changing the health of inhabitants of every continent.

The elder stateman in the realm of mosquito abatement whom we honor at the Joint Conference is one of those inspired pioneers in this field of endeavor. Guided by his master, William Herms, he has lived according to a virtue that is rapidly becoming out of date. A civilization that sets as its goal leisure with the least amount of exposure to any extreme climatic or social factors creates a generation incapable of wrestling with the many problems still to be solved. Diligent, time-consuming and fatiguing observations in the fields and forests, deserts and plains, furnishing the problems to be solved at the laboratory bench, are considered below the dignity of many. Instead of following old principles of scientific investigation, elaborate equipment, secured through enormous grants and contracts, is chosen to imitate what has never been carefully observed or studied in nature.

The symposium will unroll before you the present-day knowledge of the athropod-borne encephalitides. It will show you how much hard work and wisdom was required to assemble and interpret the fragments of knowledge. Dozens of horses had to be autopsied in the broiling sun of the midsummer heat in the Central Valley before the causative agent could be isolated in the laboratory. Inductive analysis of field observations left little doubt that the agent reached the host through the assistance of a vector. The peculiar concentration of cases along irrigation ditches was significant. But how could a vector play a role when it was impossible to find the virus in the blood of the infected? Until it was shown that for only 2 or 3 days was the blood infectious the conveyance by vectors was merely a hypothesis. At this stage a keenly conceived laboratory experiment with *Aedes* mosquitoes served as a lead to the next step which had to be taken —again in the field. With yellow fever as a model it was decided to search for the encephalitis virus in the bodies of freshly captured blood-sucking wild-caught mosquitoes. By 1941 this enterprise had proved exceptionally successful. Not only the equine encephalitis, but also the St. Louis virus, was demonstrated in certain species of *Culex* mosquitoes. Moreover, the activities of *Culex tarsalis* were closely correlated with the epidemic waves of equine and human enchephalitis.

Our clairvoyant member whom we honor clearly recognized the impact of these observations when he said in 1941 "Our work must be more intensive and directed to species which we have more or less neglected in the past in most areas." As a member of the Vector Control Advisory Committee since 1946 and as a leader in the legislature for subvention funds to control the menace of encephalitis he has effectively influenced the planning and progress in the understanding of the arthropod-borne encephalitides and their control. It is therefore proper that his colleague should, in form of papers and discussions, review the present knowledge of this very interesting group of infections.

The morning session is herewith declared open.

SOME CLINICAL ASPECTS OF WESTERN EQUINE AND ST. LOUIS ENCEPHALITIS

Wm. Allen Longshore, Jr., M.D., M.P.H.
Bureau of Acute Communicable Diseases
California State Department of Public Health

Introduction:

The clinical characteristics of patients afflicted with one of these two arthropod-borne encephalitides have been described many times in the literature, with particular regard given to the clinical picture of the specific type outbreak or occurrence being reported. (1-6)

All of these reports are confirmed by the clinical experience in California, which includes observation of the endemic occurrence of cases of both Western Equine and St. Louis encephalitis year after year. The clinician's major difficulty is one of attempting a definitive diagnosis based on a clinical examination of the patient. This problem is not readily and easily solvable as encephalitis is a syndrome which may result from many causes. The separation of these entities is essential for therapeutic as well as epidemiologic purposes. Ultimate reliance on the laboratory aids for definitive diagnosis is emphasized again and again and with this emphasis comes the equally important need for better understanding of the interpretation of laboratory results.

The attempt of this presentation is to discuss some of the areas which pose problems and result in some confusion and concern, specifically as they apply to the areas of the clinical diagnosis and the clinical management of patients evincing encephalitis symptoms.

Occurrence:

For the year 1954 there have been 635 cases of encephalitis reported to the State Health Department. Twenty-two of these have been identified as due to Western Equine virus, while 99 have been attributed to the St. Louis virus. This year's predominance of St. Louis human cases over Western Equine type human cases is not readily or satisfactorily explained on the basis of our current knowledge. Many hypotheses are possible, one of these is that the 1952 outbreak produced wide-spread immunity to the Western virus through subclinical infections, thus leaving the way open to the St. Louis virus predominating in 1954. Very little clinical activity due to either Western or St. Louis viruses was found in 1953 in spite of some 382 cases of encephalitis being reported. Comments and discussions on the presence or absence of a relationship between virus isoluation from mosquitoes and the occurrence of human cases, although a most tempting subject, will be left to other members of this panel.

TABLE 1
Acute Encephalitis by Type
1953-1954

	Total Cases** 1953	1954	Type Undet. 1953	1954	W.E.E. 1953	1954	ST.L. 1953	1954
January	15	16	6	5	..	..	..	..
February	9	29	6	5	..	..	..	..
March	24	30	6	6	..	..	..	..
April	31	34	8	8	..	..	..	..
May	36	58	9	11	..	..	..	..
June	44	82	11	18	..	..	..	..
July	51	43	20	7	4	3	7	8
August	56	96	20	48	7	5	11	55
September	49	110	26	40	3	8	3	29
October	28	100	9	44	..	6	..	7
November	17	28	6	23	..	..	..	..
December	22	9	11	5	..	..	..	..
Total	382*	635†	142	220†	14*	22*	22*	99*

*By month on onset
†Provisional—by month of report
**Totals include mumps, measles, etc. encephalitede

Causative Agent: (Etiology)

Discussion of this problem could be extensive—suffice it to state here that many agents, living and non-living, can and do produce the central nervous system involvement recognized clinically as "encephalitis." Bacteria, protozoa, spirochetes, and toxins, as well as viruses have been implicated. Hence, in the differential diagnosis the exclusion of some of the more common excitents must be carried out. A good history of exposure to childhood diseases, mumps, measles, or chickenpox, and laboratory studies are important in this matter. Spinal fluid cell counts, smear and culture, and chemistry are of value in excluding bacterial infections and in establishing the fact of the presence of an inflammatory process involving the central nervous system. Blood counts usually are unrevealing, particularly in those of virus origin. Histo-pathologic examination of post mortem specimens may reveal changes described as typical encephalitis but reveals little or nothing as to the cause of these changes. Isolation from the brain of an arthropod-borne virus is specific.

The inflammatory response of the brain to any agent is limited so in any one case the symptoms are those of an "encephalitis" regardless of the specific agent involved. For instance during 1953 and 1954, there was a wide range of causation in the total of encephalitis cases reported; mumps virus—360, Western virus—36, St. Louis virus—121, chickenpox—32, measles—94, and unknown—361. Dr. Lennette will touch upon this point further in his part of the symposium. (Table 2).

TABLE 2
Reported Cases — Acute Encephalitis
By Etiology — 1953 and 1954*

Etiology	1953	1954*
Undetermined	141	220
St. Louis	22	99
Western Equine	14	22
Chickenpox	7	25
Coccidioidomycosis	1	..
Herpes	1	1
Influenza	1	1
Infectious mononucleosis	1	..
Measles	33	61
Mumps	160	200
Rubella	..	1
Other		
Otitimedia	..	2
Pneumonia	..	2
Post vaccinal	1	1
TOTAL	382	635

*Provisional data

Clinical Picture:

There is usually little difficulty in establishing the fact that a patient has an involvement of the central nervous system plus fever. Symptoms frequently include headache, stiff neck, malaise, nausea, vomiting, tremors or twitchings, with drowsiness, lethargy, stupor or coma; all of which are related to an inflammation of the brain or an "encephalitis." Here the first problem arises—indeed the patient has the clinical findings of an encephalitis but this factual observation merely locates the site of the inflammation and unfortunately gives few clues as to the causation. Thus reported cases of encephalitis officially reported by local health departments and from which our State tabulations are originally compiled include many illnesses characterized by the encephalitis syndrome which are the result of agents, viral or otherwise, not identifiable as either Western Equine or St. Louis virus. Many of such cases have been shown by laboratory tests to be mumps, viral influenza or herpes simplex; others by their history to be chickenpox or measles, and even a larger category, about 35 per cent are finally allocated to a special category of "encephalitis—etiology unknown." (Table 2). Consideration of this last category leads to the concept persisting that one or several as yet undiscovered viral agents are playing an important role in the encephalitis picture in this State and it's encouraging to know that the search for additional agents is being continued at an accelerated pace. In order to obtain complete data and to categorize by etiology as many of these illnesses as possible, medical students have been assigned to hospitals in strategic areas of the State to obtain diagnostic materials on all admissions evidencing central nervous system involvement with fever. For the past two seasons in California, we have been attempting to have all clinical encephalitis cases reported stating etiology if known or as etiology unknown if that is the case. With this information and substantiation by the intensive laboratory confirmation program it is hoped that the resultant categories will be suitable for study and analysis. Current use of this and related data is exemplified by the bi-weekly reports provided for local health departments and mosquito abatement districts to keep them informed. (7).

It should be obvious to one and all that the individual patient's response to infection with an agent which affects the central nervous system is dependent upon a multiplicity of factors, many well recognized and many possibly unrecognized. A brief discussion seems warranted of one or two of these factors which may determine if an infected person will or will not develop the clinical disease of encephalitis.

Range of Severity:

A concept which merits further thought and consideration is the one of the "infection spectrum" of these two viral agents. There is some evidence that the arthropod-borne encephalitides in California behave in a somewhat similar fashion to other viral infections involving the central nervous system, for example poliomyelitis. The range of infection apparently includes many individuals who are infected with the virus but suffer no evident illness (subclinical infection), and the other extreme is infection leading to a fulminating disease and results in death. All gradations of illness from mild to critical fill the gap between these two extremes. This wide band of infection is a reflection of the tremendous variations possible in an individual's clinical response to the infection. These variations in clinical course have been consistent over the years our observations have been made. This response depends on many variable factors including the patient's susceptibility to the virus as determined by age, immunity, etc. and the dosage of the virus. As a result of these variables the pattern of clinical illness also deviates frequently from the typical clinical description of encephalitis. Someone has even described a group of these individuals as having "non-encephalitic encephalitis," suggesting that the signs of the infection were so mild and abortive that evidence of inflammation of the brain did not appear even though the patient's illness definitely could be attributed to Western Equine or St. Louis encephalitis virus by laboratory tests. In 1952, in an attempt to explore the clinical symptoms which might be attributed to the encephalitis viruses, all patients with fever at two County hospitals in California, were examined and of this group, two infants whose main symptoms were fever and diarrhea showed antibody titer rises to an arthropod-borne encephalitis virus which were considered diagnostic. (8). This area of inquiry could stand further investigation.

It should be admitted here that one of the major gaps in our knowledge of the behavior of these two viruses in humans is the meager information currently available on the immunity status of the population. Serologic surveys have been extremely limited. The need for some tool to help fill this void is evident, and the search for a suitable skin test is under way to help meet this need.

Differential Diagnosis:

Some idea of the extent of the problem is illustrated by Kokernot, et al (1), in a rather impressive list of the physicians' original diagnoses of patients who were shown later by laboratory tests to have had infection with either Western Equine or St. Louis encephalitis virus. The original diagnoses included polio-encephalomyelitis, bacterial meningitis, tuberculous meningitis, mumps-encephalitis, coccidioidal meningitis, lymphocytis chorio-meningitis, central nervous system syphilis, otitis media, brain trauma, brain abscess, cerebrovascular accident, convulsive disorder, cardiac failure, diabetic coma, and Sydenham's chorea. It is worth repeating here that clinically it is impossible to separate patients with viral encephalitis into etiologic categories.

One area of special interest which warranted mention in the report of the 1952 California outbreak, and which during 1953 and 1954 has continued to draw our attention, is the question of the possibility of multiple infections occurring in the same patient at the same time. This idea is suggested by the repeated occurrence of central nervous system disease with fever which clinically is diagnosed as poliomyelitis but by laboratory tests meets the diagnostic criteria for a laboratory confirmed case of St. Louis or Western Equine encephalitis. These cases have been among those diagnosed as non-paralytic poliomyelitis, spinal paralytic and even bulbar poliomyelitis. Additional specific studies on this group of patients is contemplated in an attempt to assign the responsibility for the disease process to the proper viral agent. The ability to obtain these data will depend much on the development and routine application of a simple and adequate laboratory test for poliomyelitis similar to the ones we now have for Western Equine and St. Louis encephalitis.

All the foregoing comment does not mean that under some circumstances it is impossible to be fairly well satisfied with a diagnosis of clinical encephalitis with considerable confidence that the etiologic agent is one of the arthropod-borne encephalitis viruses. In California, encephalitis with fever and convulsions during the months of June through October, in an infant, living in the San Joaquin or Sacramento Valley is a fairly good bet to be Western Equine encephalitis and is very, very unlikely to be St. Louis encephalitis. These types of epidemiologic facts previously found in California (8) (9) have maintained their constancy during the seasons of 1953 and 1954. Briefly stated, the season of disease onset continues to be sharply limited to June through October inclusive. (Table 1). The age distribution of Western Equine continues to have a large proportion (30 per cent) under the age of 1 and 50 per cent under the age of 10, while St. Louis has only 1 per cent under the age of 1 with the majority of the cases occurring between the ages of 20 to 40. In geographic distribution, the proven cases are confined in the great majority to the hot irrigated areas of the central valley of the State. With regard to sex, the distribution is still males 2 to 1.

Therapy:

Once the diagnosis of viral encephalitis is established, or while awaiting diagnosis, there is no specific therapy that may be given. Supportive measures are indicated and essential while good nursing care is of paramount importance and may mean the difference between recovery and death. (10).

In the light of the above inability to treat specifically, it is perhaps fortunate that the outcome of cases of St.

Louis and Western Equine encephalitis is in general highly favorable. The fatality rate is about 7 per cent for all of the reported acute encephalitis in the State and is much below this figure for either of the specific arthropod-borne viruses.

There is a current study of the clinical residuals that result from human infection under the auspices of Stanford Medical School. The findings of the first eighteen months follow-up of cases which occurred in 1952 will be published shortly. (11). Following the completion of this study, 4 to 8 years from now, there should be good data on the residual effects that can be expected following an acute episode of encephalitis due to the arthropod-borne viruses.

Summary:

In summary it can be said, the problem of etiologic diagnosis is a major one in a case of encephalitis; laboratory assistance is an essential part of a definitive diagnosis; further studies are indicated regarding the possibility of dual infection: search for unknown etiologic agents are warranted to fill the existing diagnostic gap; specific therapeutic treatments are now lacking; prognosis in Western Equine and St. Louis encephalitis is generally good, both with regard to staying alive and to making a "complete recovery"; and information regarding the "spectrum of infection" needs augmentation particularly with regard to information on the susceptibility of various population groups.

Much more data regarding the vector populations, infection rates, control measures, etc. are also essential to complete our knowledge in the field of arthropod-borne encephalitis but discussion of these areas has been assigned to others on this panel.

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Dr. Meyer: Dr. Longshore, this scholarly presentation is open for discussion. First, on the part of the panel. Does the panel want to add anything to this?

It might be quite appropriate if some of the people in the audience could tell us something about the recent episode in the Rio Grande Valley.

Mr. Hess: The last report we had from the Texas State Health Department was that they had isolated St. Louis, not only from collections of *Culex quinquefasciatus,* but also from the brains of two individuals that died during the epidemic. That was told to us a couple of weeks ago by people from the State Health Department. We haven't seen any written confirmation of that information, but they were convinced that it was a St. Louis epidemic.

Dr. Meyer: To what extent and over what periods did it operate? When did it start? Was it in September or October?

Mr. Hess: It apparently started earlier. I have forgotten the exact date myself. Of course, they got in late after the thing had already started, as usually happens.

Dr. Meyer: Any estimate of the number of clinical cases involved?

Mr. Hess: I saw one figure of 600, but I would hate to have that quoted.

Dr. Meyer: I've heard that figure too, but I want some authoritative statements.

Mr. Hess: The final report is going to be prepared in the near future and published; I believe, as a group of four papers. They now are being written.

Dr. Meyer: Isn't that the first time that it was conclusively demonstrated in the Rio Grande Valley?

Dr. Reeves: No, sir.

Dr. Meyer: You were once down there?

Dr. Reeves: There were clinical cases of Eastern, Western, and St. Louis in the Rio Grande Valley in 1941.

Dr. Meyer: That's a very important thing—in 1941—you were down there at that time?

Dr. Reeves: Hammond was there in 1941—Brookman and I were there in 1942. They had no cases then. (laugh)

Dr. Meyer: What about the arthropod encephalitides in horses which occurred in sections of Florida—no, Louisiana? Does anybody know anything about that? As you see, I'm trying to remove the stigma from the State of California. (laugh)

Mr. Hess: They got to the Florida outbreak late also, and I think they had only one horse case. Isn't that right, Barney?

Dr. Brookman: That was the last outbreak.

Dr. Meyer: How many horses were involved?

Mr. Mulrennan: There were 3 or 4 cases of horses. In Palm Beach County about 7 or 8 cases in horses. As soon as we heard of it, we went in and fogged and airplane-sprayed the area, and after the spraying, the infestation in the horses went to zero. We also had a case or two in Leak County on the western coast of Florida. We followed the same procedure there and the horse cases dropped to zero. I don't know whether we brought it under control or nature brought it under control, but we sure plastered the DDT and BHC around.

Dr. Meyer: If you don't mind my being facetious—we are usually controlling a disease before we understand it. This was a classical remark by the man who had a great deal to do with the elucidation of the arthropod vectors of disease. That was Theobold Smith. He made that classical remark in 1919, that—usually we control And I, therefore, always make a plea: before you go or eradicate a disease before we really understand it. around with a flit-gun, find out what it is. (laughter)

Mr. Mulrennan: That may be true.

Dr. Meyer: Yes, but the people are crying that you do something. We must always do something.

Mr. Mulrennan: Well, now that may be true, what you say, but there are other aspects you have to consider. If we sit by and do nothing and get a good full-blown epidemic, then they will run us all out of the state. (laughter) In spite of all we could do and we had experts meeting one morning as laymen and this expert from Cornell University said he'd stake his reputation on what it was. As I understood it, it was a virus called Coxackae or something like that. They say it wasn't arthropod borne. The only thing I know is this; that the city of Tallahassee and the people there lost thousands of dollars because no one in the State of Florida or no one from the other states would even stop at Tallahassee. And all of the motor courts and hotels were completely vacant. I don't know just how many cases they had, but it was several hundred, and we are still paying for it. I agree with you that it is necessary to get in and find out about these things, but in our state we depend on people coming in to stay. We don't spare the flit gun, I can assure you. (laughter)

Dr. Meyer: Well, there you are. Some one said it was a Coxsackie virus which we know is not arthropod borne; therefore we have two different opinions about it. Is it true that they have had Western Equine in New Jersey? How about that, Dr. Reeves?

Dr. Reeves: We heard Holden make that statement.

Dr. Meyer: Being brought to light that certain infection chains are maintained through contact, and don't need a vector, which is true, it is very important that we don't go away with the impression that, under certain conditions, the cycle may be maintained by other means.

I'm afraid we have to move on. Are there any questions you would like to ask?

The next presentation will be the "Veterinary Aspects" given by Dr. Ben Dean.

VETERINARY ASPECTS

Ben H. Dean, DVM

Bureau of Acute Communicable Diseases,
California State Department of Public Health

I would like to discuss briefly the prevalence of encephalitis in horses in California. When I speak of encephalitis in horses, I am referring to the western equine type because, as far as is known, St. Louis virus does not cause a clinical illness in horses. The data that I quote are from reports received by the California State Department of Agriculture from practicing veterinarians and, in turn, to the State Department of Public Health.

During the past 10 years reported horse cases varied from 442 in 1945 to a low of 27 in 1953. During this period there were reported 407 in 1952 and 54 in 1951. The reports show a sharp up and down picture; one year a high number of cases; the next year a low number. We have some evidence that these reports do not represent any lack of interest on the part of practicing veterinarians in reporting cases. As an example, in spite of very extensive efforts in 1946 to find horse cases, we only found 147, whereas in the preceding year of 1945, 442 cases were reported; in 1952, 407 were reported; and in 1949, 268 cases were reported without any stimulus.

It may be said that when outbreaks or large numbers of horse cases of encephalitis are reported, the vaccination program is stimulated so that in the following year there are less susceptibles. It may be that there is natural exposure during these high years and that the next year there are less susceptibles.

When studying the geographic distribution of reported horse cases in California, we find that there is a wide variation throughout the state. From 1947 to 1954 horse cases were reported from 55 of the 58 counties of California. Only three counties did not report a horse case. Of the 1,340 horse cases reported from 1947 to 1954 we have pretty good data on the following examples. In the south, Imperial County reported 101 of the 1,340 cases, and San Diego reported 50 cases. In the far north, Siskiyou County reported 23, and Modoc County, 30. Coastal counties also reported cases: Mendocino County, 25; San Luis Obispo County, 22; on the east side, Inyo County, 9; and Mono County, 3. We tried to make some estimate of attack rates based on estimated horse populations but did not find any significant variation.

In 1954, 51 cases were reported. These 51 cases were from 22 counties. The counties ranged from Modoc, the farthermost northeast county, to Imperial County, the farthermost southeast county. One of the valley counties (Stanislaus) had eight; Sacramento County had four; and the rest of the valley counties, one or two cases.

The study of the seasonal distribution showed that the peaks of reported cases were reached in July and August. Cases actually occurred from May up to November, but usually only one or two in May; three or four in April up to the peak; and then down to one or two in November.

We made a rather extensive investigation of the so-called "1952 epidemic." During that year 407 cases were reported. This study showed a very marked difference in the geographical distribution of the human and horse cases. The majority of the human cases occurred in the valley, whereas the horse cases were scattered. As many cases occurred in the so-called "fringe" areas—in counties outside the valley areas—as occurred in the valley. This may have been due to possible immunity of horses in the valley from prior exposure or due to the heavy vaccination that is done in the valley, as compared to these coastal or outlying counties.

The encephalitis disease picture in horses follows a very similar epidemiological pattern as that in man, in that usually one horse case is reported on a ranch and then others will be reported in widely scattered areas. Rarely has there been two horse cases on one ranch although they may have 30 or 40 horses. As far as I know, we have never had reported a horse case and a human case occurring on the same ranch.

It has been stated that horse cases occur one to three weeks before human cases. In studying our cases over a period of years, we find that this is not always true. Several times human cases were reported before horse cases. In several instances, horse cases and human cases were reported at approximately the same time. There may be a difference in reporting which would account for the fact that horse cases do not always occur first. Personally, I think they may occur earlier, later, or at the same time.

It is commonly believed that horse cases start in the south and during the summer months move north. We found this doesn't always hold true. In 1952 a large number of horse cases were reported from Riverside County in late August; at the same time horse cases in the San

Joaquin Valley were receding. In other years we have had horse cases reported in May from Tehama County, which is far north, before San Joaquin or Imperial Valley reported cases.

I might say a word regarding the vaccination of horses. The practice is quite common in California. For several years we have attempted to obtain reports of any type of encephalitis which occurred in horses that had been vaccinated for at least two reasons: (1) to find out how effective is the vaccine; and (2) if a horse is vaccinated, if the vaccine is effective; and if he develops an encephalitis, it may be that a different viral agent is involved. We are looking then for a different etiological agent.

During the period of study, we have never found a confirmed horse case in a horse that was vaccinated at least 30 days prior and not over one year. On this basis, we could assume that the vaccine probably is very effective 30 days after vaccination and up to one year.

We carried out some serological surveys of horses in the San Joaquin Valley and these surveys showed that approximately 30-40 percent of the horses had evidence of St. Louis antibodies. As stated before, no one, as far as I know, has reported a naturally occurring disease in horses due to the St. Louis virus, when inoculated intercerebrally, has produced the clinical disease.

The most extensive study in California of encephalitis in horses was carried out in 1946. At the same time the studies in horses were carried out, there were studies of human cases. Mosquito and vector control people were carrying out a study during the same period. Twelve valley counties were selected as the study area. The basis of selection was that the majority of horse and human cases had been reported from these areas. Unfortunately, 1946 happened to be a very low year as far as incidence of encephalitis—not only in California, but nationwide. The United States Department of Agriculture reported 1946 as the lowest of the 12 preceding years. I won't go into this particular study, but we attempted to find all horse cases, to obtain complete histories on each case and specimens for laboratory tests. Following the study an analysis of the data was made, and it was decided that there were many questions that we would like to have answered before further studies should be made.

In an attempt to clarify some of the questions, an experimental study relating to the pathogenesis of the disease in horses was set up. The study was carried out on the University of California campus at Berkeley at the Division of Veterinary Science. The laboratory work was under the direction of Dr. Gordon Meiklejohn. The first job was to find and buy horses that did not have western equine antibodies. Horses were bled and tested by means of the neutralization test for western antibodies and if negative, were bought and used in the experiment.

Some of the questions we wanted answered were:

1. What is the dose of western equine virus necessary to cause death or illness in horses?

2. What is the time of appearance and levels of neutralizing complement fixation antibodies after infection?

3. What is the duration of the viremia?

4. What is the incubation period?

We also threw in a fifth question as to the level and persistence of antibodies in colts foaled from mares with antibodies.

The challenge work was all done with a western equine virus that had been isolated from a horse that had died of the naturally occurring disease in Tulare County. The virus was isolated in chick-embryo.One passage was made and then used. It was not fixed in mice.

When starting the work, we attempted to simulate what we thought occurred actually in nature. Most of the challenge work in western equine and, I believe, eastern equine in horses has been done by the inter-cranial route. We felt that in nature the infection occurred through the biting of insect vectors. Therefore, we challenged these horses by inter-dermal, subcutaneous, and intervenous inoculations.

There was little information in the literature regarding the amount of virus necessary to cause clinical illness. The challenge experiments ranged from 5000 chick embryo LD-50 doses to 500,000,000 embryo LD-50 doses. Each horse that was inoculated was observed and temperatures taken for at least five days preceding the test. Following inoculation, the horses were isolated, examined, temperatures taken, bled daily for 14 days, then turned loose in a pasture and observed for the following 30 days, and on occasion brought in and bled.

Very briefly, the results of this experiment—first, the dose necessary to cause illness. The smallest dose used produced no clinical signs; with the largest dose, only one horse showed evidence of slight illness. Of the horses that were inoculated with 50,000 to 5,000,000 LD-50, five of the 15 showed clinical signs, with one death. This is in line with the field observations that the number of clinical cases is small in relation to the number that show neutralizing antibodies.

The time of appearance of neutralizing antibodies varied from two to 18 days, depending on the dose of virus used. With 5000 LD-50, neutralizing antibodies appeared in approximately 18 days. With the 500,000,000 LD-50, neutralizing antibodies appeared in 2 to 4 days. In general, the neutralizing antibodies appeared early, rose rapidly to a maximum, and stayed there only a short time. This is an important point in laboratory diagnosis if you are using the neutralizing test to show a rise in titre, because, by the time the horses were ill, they already had high neutralizing antibodies and there was little chance of showing a rise in titre. The CF antibodies, on the other hand, came much later, 10 to 20 days, and they were not affected too much by the dose of virus. Therefore, if you are using a serological test, the CF test would be the best tool to use.

The incubation period, or the temperatures of these horses, started up 7 to 8 days after inoculation. Clinical symptoms developed 8 to 11 days. Quite often the temperature peak occurred before the clinical symptoms occurred. That is in line again with practicing veterinarians' statements that by the time they are called out to see a horse, the temperature is up only a half degree and quite often down to normal.

The duration of viremia was an important question from a practical standpoint on the basis that when a horse was clinically ill, a health officer wanted the horse disposed of or eliminated immediately because of the belief that the sick horse represented a hazard to people. We found that the virus could be isolated from the blood stream of these infected horses 24 hours up to 5 days, but never later.

If the virus is circulating in the blood stream for the first five days as a maximum, temperatures occur 7 to 8 days, and clinical signs 9 to 11 days later. By the time a horse is clinically ill, I don't believe he presents a hazard because the virus is no longer in the blood stream.

A small series of mares and foals were tested. The mares were tested for neutralizing antibody and recordings made either positive or negative. When these mares foaled, we tested the colts. In all cases, if the mares had antibodies, the colts also had antibodies persisting up to three months. Whether or not these colts had sufficient antibodies to afford protection is not known. The question comes up in the valley area—should you vaccinate colts up to three months of age? Approximately 80 percent of the older horses in the San Joaquin Valley do have neutralizing antibodies. Therefore, 80 percent of the colts may be immune for the first three months.

In conclusion, I think we can say that in California, western equine encephalitis in horses presents no particular pattern that would characterize the disease from year to year. It is not an important economic problem since the vaccine is extensively used where the disease is endemic.

The most important part is its relation to the disease in man. From the standpoint of a crude index of infection, indicating the prevalence and distribution of the virus, the reporting of horse cases with following laboratory tests are very important.

The role of the horse as a possible source of infection needs more study. I know that many will differ with this opinion. But I believe that when the viremia lasts up to five days, there is a possibility that during the five-day period the horse could infect mosquitoes, which, in turn, could infect man and other horses. I thank you.

Dr. Meyer: Are there any questions?

Dr. Soper: In the horse that died of fatal infection, what was the dose and what was the incubation period in that particular animal?

Dr. Dean: The dose, Dr. Soper, was 500,000 chick embryo LD-50. The horse showed clinical signs on the eighth day. It was about 48 hours earlier than the average. I believe the temperature started up on the sixth day. We temperatured the horses twice daily. Many times we picked up a temperature of 104° F. and the horse showed no signs of illness so that if a farmer or someone else had been using these horses, he would never have noticed anything wrong.

Dr. Meyer: In experiments we did about 25 years ago, 20 horses were inoculated intercutaneously with the 150,000 guinea pig doses. (At that time we didn't have the means to propagate the virus in the egg; that only came up in 1934.) None of these horses showed any clinical signs, though they ran a fever.

A very distinct opposite was that the same dose was then given by a veterinarian at Davis, who thought this was a marvelous way to immunize his riding horse, a hunter. He inoculated the same dose intercutaneously and 12 days later he called me up and asked if I would come up and do the post mortem on his horse. So you see there may be individual variations in the disposition to accept the virus. That was quite clear in subsequent years when actually the horse populations of the valley became so inherently immune you had to do your experiments on 4-5 month old colts. You could not experiment any more by the cutaneous route with the dose of virus we had chosen. We had to transfer the virus entirely by the intercerebral route. That whole question is still wide open with regard to the variability of the individual horses to accept this virus.

I remember in Hammond's day when he tested, we had to get the horses from an area in Nevada to really produce an infection in them. I think your point is an exceedingly interesting one, that probably overwhelming doses may produce an entirely different physiological effect on that virus and small doses which progressively invade the central nervous system.

ETIOLOGIC ASPECTS OF THE INFECTIOUS ENCEPHALITIDES

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My discussion this morning is directed at certain problems concerning the etiologic agents of the infectious encephalitides. The term "encephalitis" is a generic one and clinically is applied to any set of symptoms and physical findings which point to an inflammatory condition of the brain as the cause of the patient's illness. The underlying cause is not always easy to ascertain, as the condition can be produced by such diverse agents as toxic gases, noxious chemicals, cerebro-vascular accidents, biological agents, etc. Infectious encephalitis, i.e., that due to biological agents, can be caused by protozoa, fungi, bacteria, viruses and rickettsiae. Our concern this morning is with two aspects of this very large problem; namely, with viruses as the inciting agents of encephalitis and with the transmission of these agents by vectors, especially mosquitoes, i.e., in the so-called arthropod-borne viral encephalitides.

At the present time, two major arthropod-borne viral encephalitides are recognized in California. These are Western equine encephalitis and St. Louis encephalitis. The Western equine encephalomyelitis virus reported by Meyer in 1931 as the cause of encephalitis in *equidæ* in the San Joaquin Valley was shown by Howitt in 1938 to be involved in the causation of human infections. In 1939, Howitt showed, through serologic methods, that the St. Louis encephalitis virus is also responsible for a proportion of human infections diagnosed as encephalitis. Since that time, both viruses have been recognized to cause a high proportion of the encephalitis in the Central Valley, and *Culex tarsalis* has been shown by Hammon and Reeves to be the primary, or at least the most important, vector in the transmission of these viruses to man. It is only natural, therefore, that these viruses should be of peculiar interest to California—not only because the human and equine morbidity they produce is not negligible, but also because the solution of some of the dominant epidemiologic problems may provide a key to the epidemiologic riddle posed by the arthropod-borne viral diseases as a group.

To give an idea of the prevalence of Western equine and St. Louis encephalitis in man, we have prepared Table 1, which shows the occurrence of laboratory-proved cases over the ten-year period 1945-1954. It will be observed that in some years the prevalence has been high and in others low. Of the last five years, there were three with a high prevalence of Western equine and St. Louis encephalitis. It will be seen that in 1950 there were 157 laboratory-proved cases of encephalitis, about equally divided between the Western equine and St. Louis types. In 1952, there were 414 cases, of which 370 were due to the Western equine virus and 44 were due to the St. Louis virus; and in 1954 there were 118 cases with 22 ascribed to the Western equine virus and 96 to the St. Louis virus. We might point out that the 1952 outbreak was one of the largest on record, approximating, in terms of the total number of cases reported, the encephalitis outbreak of 1941 in Minnesota and contiguous areas.

It is of interest to note, as shown in Table 1, that as the number of cases of Western equine or St. Louis encephalitis increases, the total amount of encephalitis reported also increases, although even in years in which there is a low prevalence of Western equine or St. Louis encephalitis an appreciable number of cases of so-called "infectious encephalitis" is reported. The term "infectious encephalitis" is placed in quotation marks because into this category are placed all cases of encephalitis of presumed infectious origin, whether the encephalitis be a primary manifestation of infection or whether it be secondary to some other condition. In other words, this category includes not only the arthropod-borne viral encephalitides and encephalitis due to agents such as the viruses of mumps and of herpes simplex, as well as encephalitis following such infections as measles, chicken pox, influenza and mumps, but also post-vaccinal encephalitis, lethargic encephalitis, etc. In Table 2, we have taken the cases of infectious encephalitis reported during 1953 and 1954 and made a breakdown into categories which include laboratory-proved Western equine or St. Louis encephalitis, a category called "etiology undetermined," and a fourth category designated as "other." The "etiology undetermined" category includes those cases of encephalitis in which laboratory studies have failed to reveal any known biologic agent as the cause. The category "other" includes those cases due to measles, mumps, chicken pox, influenza, post-vaccinal encephalitis, etc., i.e., encephalitis which is supervenient to some known naturally occurring infection, or upon attempts to induce an artificial active immunity (e.g., smallpox or rabies immunization). It is readily noted from Table 2 that the category "etiology undetermined" is of an appreciable size and it is reasonable to suppose that an unknown proportion may be due to a virus or viruses.

In an attempt to ascertain, if possible, what relationship, if any, there might be of these unknown encephalitides to Western equine or St. Louis encephalitis, tabulations similar to that given in Table 3 were prepared. Inspection of Table 3 suggests that during 1953 the number of cases of encephalitis of undetermined etiology increased during the summer and early fall, whereas the number of cases in category "other" was largest in the spring and early summer. Since this category includes encephalitis due to such diseases as mumps, measles, chicken pox, etc., which have a high incidence at this time of the year, this concentration is understandable. If we take the data for the year 1954, a year of relatively high prevalence of encephalitis, the trends are much more suggestive. There is a peak incidence of unknown encephalitis during August, September and October with 130 of the 193 cases occurring in this interval. The number of cases of unknown encephalitis and of St. Louis encephalitis suggests a similar degree of prevalence, although this may be only coincidental and of no significance. Ideally, from the epidemiologic standpoint, every case of encephalitis should be accounted for on the basis of etiology, and the discrepancy between the total number of cases of infectious encephalitis reported and the number ascribable to the Western equine or St. Louis virus or to agents in the "other" group leaves a large, albeit variable, residuum of cases which in major part falls into the "etiology unknown" group. This discrepancy has been repeatedly observed by us and was especially noticeable in 1952 and, as just mentioned a few moments ago, has led to the working hypothesis that another virus or viruses may be etiologically involved. This point will be touched upon again a little later, but before leaving this aspect, it might be pointed out that it provides an excellent illustration of the fact that in the epidemiologic investigation of infectious disease the field and the laboratory are so interdependent that close collaboration is a *sine qua non* for success. In the case of viral diseases, this close cooperation is especially necessary, and one might even say mandatory.

Because of the importance of *Culex tarsalis* as a vector of Western equine and St. Louis encephalitis viruses, as shown by Hammon and Reeves, mosquitoes were collected in several areas in the Central Valley in 1952 with a view to determining infection rates in mosquito populations. Unfortunately, this attempted study, which in retrospect could have yielded much valuable, even if circumscribed, information, came to naught. The collection of mosquitoes was not initiated until August, i.e., at the peak of the outbreak, at which time the entomological field teams were augmented and some effort could be diverted from strictly control measures to mosquito collection and identification. Augmentation of the medical and entomological field teams permitted the increased collection of human clinical and arthropod material, but ironically the laboratory, the third member of the investigative triumvirate, was provided with no additional means to handle this great volume of material, dumped upon a staff already overwhelmed with clinical material submitted by physicians and health officers. It thus became necessary to store all of the entomological material and much of the clinical material until such time as opportunity would be afforded for examination. Unfortunately, the dry ice storage facilities were completely utilized with material obtained early in the epidemic, and it was necessary to rent additional facilities. Storage in this latter was not under optimal or ideal conditions and in examining the arthropod material during the winter of 1952-1953 only one strain of Western equine encephalomyelitis virus was recovered from the large number of mosquito pools examined, i.e., storage under less than the ideal conditions had resulted in the loss of any viruses which may have been present in the specimens. That it was storage rather than the techniques used was indicated by the fact that the same techniques applied to mosquitoes stored under optimal conditions by Doctor Reeves resulted in the recovery, on a proportional basis, of as many strains in our laboratory as in Doctor Reeves's. In 1953, a program for the collection of *Culex tarsalis* mosquitoes and testing for the presence of Western equine and St. Louis viruses was set up as a collaborative study between the Viral and Rickettsial Disease Laboratory and the Bureau of Vector Control of the California State Department of Public Health. On the basis of the funds available, it was feasible to make weekly collections in only two areas — one in Fresno County and one in Kern County. In 1954, the program was augmented so that it was possible to collect and test immediately *Culex tarsalis* from four areas—Kern, Fresno, San Joaquin and Sutter-Yuba Counties. Twelve pools comprising 50 *Culex tarsalis* each were collected in each area, making 48 pools per week over the season when Western equine and St. Louis encephalitis might be expected to occur in man. Mosquitoes from the field collections were sorted, identified, and shipped to the laboratory on dry ice, where they were tested within 24 to 48 hours after receipt. Each pool was ground into a suspension with buffered saline solution containing serum, centrifuged at very high speed to remove detritus and large micro-organisms, and the supernatant fluids treated with antibiotics to destroy remaining bacteria. These suspensions were inoculated into adult mice and into embryonated hen's eggs. These two hosts were used because, as mentioned previously, we were looking primarily for the Western equine and St. Louis viruses. In future work, we hope to use baby mice in a search to possible unknown viruses that are arthropod-borne. These viruses may not necessariy be encephalitogenic for man, but we are engaged in a cooperative program with the Division of Medicine and Public Health of the Rockefeller Foundation aimed at determining what viruses are present in the arthropods of the Central Valley and their relationship, if any, to human disease, febrile or otherwise. The usefulness of baby mice for such a purpose is attested to by the experience of Taylor in Egypt who recovered a number of viruses from arthropods (mosquitoes, ticks) and from humans and found that most of these agents were pathogenic for baby mice but not for adult mice.

The results of the examination of 989 pools of mosquitoes over the six-month period May through October 1954 are given in Table 4. These 989 pools comprised a total of 41,415 mosquitoes. It will be noted that somewhat smaller numbers of pools were tested at the beginning of the season and again at the end of the season due to the paucity of mosquitoes; sometimes it was necessary to combine pools in order to get adequate numbers of mosquitoes for testing. It will be observed from Table 4 that the Western equine encephalomyelitis virus was isolated from *Culex tarsalis* as early as May, when the collections were begun, and as late as October, when collection was terminated. The highest proportion of virus isolations was in June and July when 25 per cent and 31 per cent of the pools respectively were positive (see Table 5). On the other hand, no isolations of the St. Louis virus were made in May or October, but isolations were made during the four months in between. The peak of the St. Louis encephalitis virus recoveries was in August when 20 per cent of the 222 pools tested yielded this virus. Examining the findings for the entire season, it will be seen that of the 989 pools examined 72 per cent failed to yield any demonstrable agent, 15 per cent proved to be positive for Western equine encephalomyelitis virus, and 9 per cent for the St. Louis encephalitis virus.

It is when the virus recoveries are broken down by month rather than by taking the total picture for the season that items of interest emerge. Thus, the monthly distribution of the mosquito infection rates, i.e., the number of positive pools, correlates in a rough fashion with the occurrence of human cases of Western equine and St. Louis encephalitis. From morbidity reports and from laboratory studies, we know that cases of Western equine encephalitis occur in largest numbers in early and midsummer, with the peak incidence falling at this time, whereas St. Louis encephalitis tends to show a concentration of cases in the late summer and early fall. It will be observed in Table 4 that the type of virus isolated, as well as the number of isolations, followed this pattern—the Western equine encephalomyelitis virus was recovered earlier and in a larger proportion of cases than was the St. Louis virus and as the season advanced, the number of recoveries of the Western equine virus decreased as the number of St. Louis virus recoveries increased. This relationship is better illustrated in Table 5, in which the distribution of Western equine and St. Louis encephalitis cases is compared to the isolation of these viruses from mosquitoes, i.e., in essence, mosquito infection rates. Using 1954 data, and tabulating by month of onset of illness or month of virus isolation, gives us Table 5, which shows that the mosquito infection rate was higher with the Western equine virus than with the St. Louis virus early in the season, reached a peak before the mosquito infection rate with St. Louis encephalitis virus attained its peak, and then declined as the St. Louis virus infection reached its peak. The comparison is drawn on too few human cases to permit formulating any definitive conclusions, but the trends are most suggestive. Despite the heavy infection rate with Western equine virus in mosquitoes, the number of human cases of Western equine encephalitis which occurred was small. This may be due to an extensive and effective subclinical immunization with Western equine encephalomyelitis virus during the course of the 1952 outbreak so that the proportion of susceptible individuals in the human population is still too low for a large outbreak to occur even if this mosquito infection rate represents a norm during the average year. The density of the mosquito population is also an important factor, but we believe it is quite probably less so that the immune status of the human population. In the case of the St. Louis virus, Table 5 shows a somewhat better correlation between the number of human cases which occurred and the infection rate in mosquitoes—the peak infection rate in *Culex tarsalis* was followed by the peak infection rate in man. Because of the relative paucity of human cases in any one year, comparisons can best be made on accumulated data. Therefore, Table 6 was prepared, arbitrarily choosing the accumulated number of cases over the six-year period 1945-1950 to compare with the 1954 data on mosquitoes. (In this analysis, the 1952 data were not used because this was a year not only of an extremely high incidence of human cases, but also the situation as concerns the density and geographic distribution of the *Culex tarsalis* population was highly unusual. Subsequent analyses, however, will take into account data collected during 1952.) Table 6 brings out some interesting relationships. First, human cases of either Western equine or St. Louis encephalitis do not appear until the mosquito population is infected. Second, infection of both the mosquito and man (encephalitis) precedes infection with the St. Louis encephalitis virus. Third, as the infection rate rises in mosquitoes the number of human cases increases. Finally, as the infection rate of mosquitoes decreases, human cases also decrease and when the virus disappears, no cases occur. The true significance of such correlations will be revealed only after additional years of study of the infection rates in mosquitoes. It is hoped that such studies will permit, from collation of *Culex tarsalis* density and infection rates, the establishment of an index or indices that will serve as a warning that outbreaks are imminent or that control should be intensified to avert impending outbreaks.

Before closing, I should like to touch upon one other aspect of the encephalitides which has been turned up by laboratory studies, namely, encephalitis of undetermined etiology. Each year an appreciable proportion of all the cases of encephalitis falls into this category. As shown in Table 3, in 1953 there were 124 cases in this category, and in 1954, there were 193. As has been previously mentioned, it is reasonable to believe that an unknown proportion of these cases may be due to viral agents. While cases of undetermined etiology occur throughout the year, they increase in number during the summer and early fall, as is shown in Table 3, thus suggesting that arthropod transmission may be involved in producing at least some of these infections. During 1954, as shown in Table 4, we isolated, from pools of *Culex tarsalis,* "viruses" which have been found to be neither the Western equine nor the St. Louis encephalitis viruses. Also, they do not appear to be the California virus first described by Hammon and Reeves, but in some respects (pathogenicity for laboratory animals) resemble the Sindbis virus isolated by Taylor from *Culex* mosquitoes in Egypt. Whether these 42 agents are all strains of a single virus or whether they represent several viruses is unknown and identification studies are under way at present. Nevertheless, it is of interest that of the total of 280 strains of virus isolated from *Culex tarsalis* during the 1954 season, 54 per cent were Western equine, 31 per cent were St. Louis encephalitis, and 15 per cent represent the as yet unidentified virus or viruses.

One is highly tempted to believe that an agent recovered with such frequency and producing an infection rate in *Culex tarsalis* about one-half that produced by the St. Louis virus must play some role in the causation of human illness. However intriguing this possibility, we can say at the moment only that the pathogenicity of this virus or viruses for man is unknown. To ascertain if there were any correlation between this virus and cases of encephalitis of undetermined etiology the data at the bottom of Table 5 were put together. If any relation does exist, it is not obvious from these data. Most recoveries of the agent were made in June and July, when the prevalence of cases of encephalitis of undetermined etiology was low, whereas few or no recoveries were made in August and September, when such cases were at their maximum prevalence. It is not impossible, however, assuming that the unknown agent is pathogenic for man, that most cases of encephalitis of undetermined etiology occur during the early summer, and that similar cases in the late summer and early fall are due to another, unknown, etiologic agent. The data may also be misleading in that the high incidence of encephalitis of undetermined etiology in the late season may be more apparent than real and due in part to the inclusion in this category of cases of non-paralytic poliomyelitis which are mistaken for a mild encephalitis. With in vitro tests now available for poliomyelitis antibody assay, and the possession of a new agent with which it will be possible to do serologic surveys and diagnostic work for antibodies against this agent, future studies should contribute further to the difficult problem of resolving the etiology of these cases of encephalitis of undetermined origin. If successful, this should permit us to split off another fragment of this large group, as has previously been done when the presence of the Western equine and St. Louis viruses in the Central Valley was recognized.

Finally, it is also possible that encephalitis of undetermined etiology, especially that occurring in the early spring, may be due to a virus carried by mosquitoes other than *Culex tarsalis.* Since our major interest has been to study the epidemiology (including control) of Western equine and St. Louis encephalitis, arthropod studies have been restricted entirely to *Culex tarsalis.* We have not, however, overlooked the possible role of other mosquitoes in transmitting unknown viral infections to man. In an attempt to ascertain what the situation might be concerning the transmission of unknown viruses by arthropods in California, a cooperative study has been undertaken by the Division of Medicine and Public Health of the Rockefeller Foundation and the Viral and Rickettsial Disease Laboratory of the California State Department of Public Health. Mosquitoes, as well as other arthropods, are being collected and examined for the presence of viruses. If, and as, such agents are recovered, serologic surveys will be made to ascertain the extent to which human infection with these agents occurs, as well as to ascertain their role in the causation of human encephalitis or other illness.

TABLE 1

Distribution, by year, of laboratory-proved human cases of Western equine and St. Louis encephalitis

Year	Cases reported*	Laboratory-proved cases of Western equine and St. Louis encephalitis: Total	W.E.E.	S.L.E.
1945	302	54	26	28
1946	160	28	18	10
1947	127	38	32	6
1948	71	1	0	1
1949	80	31	10	21
1950	357	157	88	69
1951	146	55	22	33
1952	792	414	370	44
1953	335x	36	14	22
1954	582x	118	22	96

* Cases in category "infectious encephalitis"

x Provisional figures

TABLE 2

Infectious encephalitis by category, 1953-1954

Year	Cases reported*	Etiology undetermined	W.E.E.	S.L.E.	Other
1953	335	124	14	22	175†
1954	582	193	22	96	271†

Figures from January 1 through November 13 of each year.

*In category "infections encephalitis"

†Of these, 131 and 185 were due to mumps virus in 1953 and 1954 respectively.

TABLE 4

Results of examinations of mosquitoes *(Culex tarsalis)* for infection with W.E.E. and S.L.E. viruses, 1954

Month of collection	No. of pools tested	No. of mosquitoes	Results, in terms No. of pools: Negative	Positive: W.E.E.	S.L.E.	Unident. agent
May	106	4,370	99	7	0	0
June	203	9,082	134	50	5	14
July	176	8,290	81	54	20	21
Aug.	222	10,413	140	34	45	3
Sept.	166	6,541	140	5	17	4
Oct.	116	2,719	115	1	0	0
Totals	989	41,415	709	151	87	42
	100%		71.7%	15.3%	8.8%	42.2%

TABLE 3

Distribution, by month of onset and by category, of infectious encephalitis, 1953-1954

1 9 5 3

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Etiology undetermined	7	8	2	7	8	12	10	14	16	25	7	8	124
W.E.E.	..	..	..	..	..	..	..	4	8	2	..	..	14
S.L.E.	..	..	..	..	..	..	..	..	10	11	1	..	22
Other*	.........48.........				22	30	31	17	8	10	9	x	175
					1 9 5 4								
Etiology undetermined	.........23.........				11	19	7	28	60	42	3	..	193
W.E.E.	..	..	..	..	..	..	..	6	13	3	..	..	22
S.L.E.	..	..	..	..	..	..	..	14	53	29	..	..	96
Other†	.........85.........				47	63	34	13	14	14	1	x	271

* Of this total of 175 cases, 132 were attributed to mumps virus.
† Of this total of 271 cases, 185 were attributed to mumps virus.

TABLE 5

Relation betwene occurrence of human encephalitides and presence of virus in mosquitoes *(Culex tarsalis)*, 1954

W.E.E.	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
Cases	..	..	..	6	13	3	..	22
Pos. Pools	7/106	50/203	54/176	34/222	5/166	1/116	..	151/989
S.L.E.	6.6%	24.6%	30.7%	15.3%	3.0%	0.9%	..	15.3%
Cases	..	..	..	14	53	29	..	96
Pos. Pools	0/106	5/203	20/176	45/222	17/166	0/166	..	87/989
Et. und.	0.0%	2.5%	11.4%	20.3%	10.2%	0.0%	..	8.8%
Cases	11	19	7	28	60	42	3	170
Pos. Pools	0/106	14/203	21/176	3/222	4/166	0/166	..	42/989
?-virus	0.0%	6.9%	11.9%	1.4%	2.4%	0.0%	..	4.2%

TABLE 6

Percentage distribution of human cases W.E.E. and S.L.E. by month of onset compared to percentile infection rates in *Culex tarsalis*

W.E.E. cases, 1945-50*	Jan.-Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
W.E.E. pos.	..	..	5.2%	40.2%	35.6%	16.7%	2.3%	..	..	100%
mosq. pools,			(9)	(70)	(62)	(29)	(4)			(174)
1954	..	6.6%	24.6%	30.7%	15.3%	3.0%	0.9%	..	..	..
		(7/106)	(50/203)	(54/176)	(34/222)	(5/116)	(1/116)			
S.L.E. cases, 1945-50*	..	..	..	5.9%	33.3%	48.2%	12.6%	..	..	100%
S.L.E. pos.				(8)	(45)	(65)	(17)			(135)
mosq. pools,	..	0.0%	2.5%	11.4%	20.3%	10.2%	0.0%	..	..	..
1954		(0/106)	(5/203)	(20/176)	(45/222)	(17/166)	(0/116)			

*Data from Lennette, E. H., and Longshore, W. A., Jr. California Med., *75:* 189-195 (Sept.) 1951.

EPIDEMIOLOGICAL ASPECTS OF ENCEPHALITIS UNDER FIELD CONDITIONS[1]

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Other speakers on this panel have discussed and will discuss separately the multitudinous factors of the hosts, parasites, vectors and environment as they relate to the arthropod-borne encephalitides. I would like to review the circumstances of our present knowledge of the interrelationships of these various biological factors in nature which we might call the "Epidemiological Aspects Under Field Conditions." Generally the discussion will be centered on the infections caused by the Western equine and St. Louis viruses because they represent a problem in the Western United States.

It should be valuable to compare and contrast the status of our knowledge of these agents with that of other mosquito borne diseases, and fiinally we may find it desirable to investigate the possible application of this information to a control program.

The Basic Infection Chain

Much current and past research has been devoted to obtaining a complete knowledge of the ways in which the Western equine and St. Louis viruses propagate and maintain themselves in vectors and hosts in nature. It is constantly anticipated that a knowledge of the basic infection chain will offer one or more approaches to a practical and economically feasible control procedure.

Vectors

Demonstrations of high *Culex tarsalis* infection rates with Western equine and St. Louis viruses in California have been reviewed repeatedly for this group. Until recently, such studies were concentrated in Kern County. However, the program conducted by the State Department of Public Health in the past several years, in cooperation with Mosquito Abatement Districts, now enables us to say that *C. tarsalis* is similarly infected in widely separated geographical areas of the Central Valley. It is interesting that similar findings have occurred in unreported studies of other research groups in several other western states. Up to the present, data indicate that species of mosquitoes other than *C. tarsalis* found naturally infected are secondary vectors and their infection is largely a reflection of the vector activities of *C. tarsalis.*

Considerable interest has been expressed in the epidemiological interpretation of the extensive information on vector infection indices under field conditions and the application of these data as an aid to control programs. We must admit that we are still uncertain of how such indices can be related directly to determine risk of human or horse clinical disease. However, progress is being made in what amounts to a new area of application. It must be realized that this type of information has never before been obtained for an arthropod-borne virus disease. A vector infection index has never been determined or applied as a guide to the measure of public risk or control operations, even in such well-known diseases as epidemic yellow fever, dengue fever or sand fly fever. Actually, *Aedes aegypti* naturally infected with yellow fever have never been found in the Americas and have been found only seven times in Africa. The isolations of yellow fever virus from jungle vectors have been sporadic and in small numbers of vectors or isolations and have never been applied as an index to transmission. In the other examples, such as dengue and sand fly fevers, adult vectors have not been shown to be infected in nature. This undoubtedly comes as a surprise to most of you.

In two mosquito borne diseases, malaria and filariasis, accurate measurement of vector infection rates has been possible and has been applied in indices to the risk of human infection. However, in both of these instances there are obvious differences from encephalitis, because circumstances allow comparatively easy determination of the indices and their application. It is practical in malaria and filariasis to examine visually individual mosquitoes to establish infection rates, rather than to test pools of mosquitoes, as in encephalitis, by more indirect and time-consuming methods. Additionally, in both malaria and filariasis man is the sole source of infection for the vector and the only receptive host to which the vector can transmit. A review of the literature on malariology and filariasis from Ross to the present day cannot help but impress one with the relatively little application of vector infection indices to determine the effectiveness of control measures or risk of infection. Much more weight has been placed on measurements of infection indices in humans, the size of the vector population, and its rate of contact with man.

These measurements have been applicable because of the comparatively simple basic infection chain involving only man and the mosquito vector. Yet it still has been a most difficult task to apply the indices with accuracy.

Our knowledge is very inadequate on such basic problems as the amount of the encephalitis virus it takes to infect different mosquito species, the proportion of an exposed vector population that subsequently can transmit, the dose of virus a vector can inoculate, and the environmental conditions required for virus survival in and transmission by a vector. Recent publications from the Montgomery Laboratory of the Communicable Disease Center are the first attempt to measure accurately a few of these variables.

It can be said with assurance that an adequate beginning has been made in establishing encephalitis vector infection indices under field conditions, particularly in California. Indeed there is more of such information available than in any other area of the world, and it is comparable in quality to that for most arthropod-borne diseases. The remaining problem is to learn how it can be reliably applied to the other biological factors we will now discuss.

Biology of Vectors

Detailed consideration of the general biology of a vector such as *Culex tarsalis* is not in the scope of this paper and is discussed by other speakers on the program. However, certain phases of vector biology must be considered. I would like to emphasize one aspect of biological activities of the vectors of the encephalitides—a key to understanding the epidemiology of these infections in the field.

We can easily become thoroughly conditioned to think that the proportion of a mosquito vector population which succeeds in biting man is all-important in the perpetuation of the disease. In classical infections such as epidemic yellow fever, dengue, malaria and filariasis, this is certainly the case; indeed to be successful an individual vector must bite man two or more times and

[1]This investigation was supported in part by a research grant C-481 (C6) from the National Micro-Biological Institute of the National Institutes of Health, Public Health Service.

frequently or the infection will die out. However, in encephalitis the vector attack rate on man is of no significance in perpetuating the parasite; a very small proportion of the population of *C. tarsalis* ever feeds on a person, probably rarely more than once. Field data indicate that approximately 75 per cent of the feedings of *C. tarsalis* are on birds and 25 per cent on mammals. Less than one per cent of the *C. tarsalis* population probably succeed in feeding on human beings. This rate undoubtedly fluctuates under varying conditions, but it is useful as a general index. An infection dependent on human-to-human transmission would quickly disappear with such a low rate of vector-host contact; however, the basic encephalitis infection chain thrives under such conditions, because the source of vector infection is the avian population and feeding on humans is incidental. With this concept well in mind, we can appreciate how it is possible each summer to have high *C. tarsalis* virus infection rates in many areas, even a fairly dense *C. tarsalis* population, few complaints from our citizens concerning attacks by *C. tarsalis,* and only a few or even no recognized human cases of encephalitis in the same area. Factors of inapparent human infections and immunity, of course, also play a contributory role in this phenomenon. This concept explains how we can have circumstances of a very low vector population in a highly urbanized situation and still have sporadic human cases. It also assists greatly to explain how we can have an epidemic situation such as the one in 1952, when the vector population is greatly increased and the usually low vector human attack rate then reaches significant levels. Factors such as earthquakes in Kern County undoubtedly increased vector-human association by stimulating people to remain out of their homes in the evening.

Relating vector population indices to the important factors of both vector-human and vector-avian host contact rates, while essential, is not simple to obtain. We have even had to go so far afield as to carry out studies on the epidemiology of avian malaria to be certain of the intimate relationship of *C. tarsalis* to the many species of wild birds. New tools, such as the development of mosquito bait traps using wild birds as bait, offer further promise.

The extensive current studies on the biology of *C. tarsalis* in numerous areas will undoubtedly lead to knowledge which will further assist in an understanding of the relationships of this species to its animal hosts.

We should consider in more detail the role of vertebrate hosts as a part of the basic infection chain before attempting to discuss further the interrelationship of all these factors.

Vertebrate Hosts

Man and horse, the two hosts in which these viruses may produce clinical disease, are probably insignificant as sources of vector infection. We must recognize that even in these two host species the vast majority of infected individuals do not become clinically ill but have inapparent infections. In other mammalian species and birds, infection may occur very frequently in the field but has not been observed to cause a disease. Other encephalitis agents such as Eastern equine and Japanese B viruses are an exception to this rule but have not been found in the area with which we are concerned.

There is ample evidence that a wide range of wild and domestic bird species are frequently infected with Western equine and St. Louis viruses. These wild and domestic birds are believed to be the important sources of vector infection. Infection in those few bird species studied in detail has generally been characterized by the appearance of virus in the blood in high concentrations for a short period of time and a lack of clinical disease.

Although an intensive effort has been made, we are still far short of a complete understanding of the dynamics of infection in the many species of birds in which evidence of infection in any endemic area can be found.

There is undoubtedly a great difference in the amount of virus various bird species may have available in their blood for vector infection. Results on this significant problem as related to Eastern equine virus have recently been published by the Communicable Disease Center laboratory group.

One can appreciate the difficulty of studying this type of problem in the field, and it is not simple to study wild birds in the laboratory. Available data and current studies will undoubtedly help determine which of the wild bird species are the primary sources of vector infection. This remains a most important field for further basic work.

General Considerations

Let us come back now to a consideration of the levels of vector populations, vector infection indices, and availability of avian sources of vector infection which may lead to a high risk of the occurrence of clinical encephalitis in a human population. Some specific examples of field situations may exemplify the variability of conditions.

The first example is a rural area we have studied intensively for a number of years. Each summer there is a very high *Culex tarsalis* vector infection index, averaging approximately one of every hundred specimens infected in the field during the summer. There is a very large *C. tarsalis* population each summer. There is evidence of widespread infection in the abundant wild bird population of the area. In spite of these circumstances and of the fact that residents are frequently bitten by *C. tarsalis,* there has not been a recognized clinical case of encephalitis in the human or horse population of the area for a number of years. Surveys of the immunity status of this population indicate that a high proportion of individuals have been infected but did not become ill. The total human population of the area is only about 150 persons, and the chances are probably quite small that more than one person would develop encephalitis if all individuals of a group of non-immune people of this size were infected at one time. The present status of immunity in a high proportion of this group even further decreases the chance of a clinical case in any one summer. There is constant possibility that an infected vector will bite a susceptible host with clinical disease resulting, but the odds are against it.

The second example, one already mentioned, is the 1952 epidemic. In this instance all of the conditions in the previous example were present, but one important factor was different. A very large susceptible human population was exposed. Undoubtedly many persons became infected, of whom the expected proportion developed the clinical disease. This is a highly simplified description of the situation, but one in which we can express considerable confidence.

The third example to be cited is our study of a city in a highly endemic region in which a very effective *C. tarsalis* control program was achieved. In this instance the vector population index was low enough that one might expect no transmission to result. There was still a large population of susceptible humans and birds. In these circumstances virus was still found in the small vector population, although only 100 *C. tarsalis* could be collected in the entire summer; and there was evidence of current infection in a population of 100,000 persons. However, the infection persisted in the basic cycle; and one could even expect that if a large population of the vector built up even in a neighborhood of the city, the rate of transmission would build up and a clinical human case might result.

Somewhat similar circumstances occurred in the DDT control program of *C. tarsalis* in Kern County chicken houses in 1945. A 95 per cent reduction of the *C. tarsalis* population in chicken houses did not break the infection chain or even reduce the vector infection level or transmission rate to birds.

The last example is a rural area along a small stream where conditions were ideal for the building up of a very large population of *C. tarsalis*. In this situation, although studied for a period of years, there was only one year in which infection rates were high in the vector. The low rates in most years apparently were due either to the constant dilution of the vector population by newly emerged adults or to the absence of a sufficient population of avian hosts to allow a constant transmission chain.

Up to the present time a situation has not been observed in which there was strong evidence of one of these viruses having been reintroduced into an area. Rather it has appeared that both Western equine and St. Louis viruses succeed in maintaining themselves in the situations studied.

Even though a vector population is controlled and held at a low index as determined by our measuring tools, virus transmission may continue at a low level in the avian host-vector cycle. Under such circumstances the odds are quite small that clinical cases in man will occur frequently. Either the free-moving, unrestrained, infected vectors or the avian hosts may always invade an uninfected area, and if a sizeable vector and avian host population is available, a situation may result in many ways comparable to the Lake Vera malaria outbreak. A noticeable difference would be that most of the human encephalitis infections would be inapparent clinically, as contrasted with malaria.

The preceding discussion has been related largely to the epidemiology of these infections in the summer period. There has long been a question concerning the mechanism by which these viruses survive through the winter. Investigations on this reservoir phase of the infection cycle are being intensively pursued by several groups at this time. Most of the emphasis of these studies is directed at determining if some facet of the mosquito vector-avian host cycle will account for virus survival. Unfortunately a detailed account of results cannot be presented at this time. Current data strongly indicate that the Western equine virus does persist in the vectors or hosts through the winter period in at least one area. Reintroduction of virus each summer from other areas probably does not occur. Another year of accumulated data may permit the reporting of these factors in the reservoir problem.

To conclude the consideration we might review the probable effects of the vector control program on the encephalitis problem. It is apparent that our current goal cannot be the eradication of these infections. The fact that the infections are perpetuated in a basic cycle of a very common mosquito and a wide range of common wild birds makes this an unrealistic current objective. A vector control program can be expected to effect a marked reduction in the prevalence of infection and diseases in man. In those past years when control programs and natural conditions have resulted in a relatively low *Culex tarsalis* population, we have seen a relatively small number of human cases. Obviously the infection chain balance was sufficiently precarious at these times that any further decrease in the vector population would have been beneficial. Our goal must always be to increase further the odds against a large number of persons being exposed to infection. We certainly know sufficient about the basic epidemiology of the encephalitides under field conditions to be able to endorse and sponsor such action.

A quotation from a recent letter from Dr. Fred L. Soper, Director of the Pan American Sanitary Bureau, to Dr. L. W. Hackett, is perhaps illustrative of the philosophy of yellow fever workers:

> "It is a pleasure to assure you no one has ever been able to isolate yellow fever virus from *Aedes aegypti* infected in nature in the Americas during the twenty-five years since laboratory animals have been available for this purpose. Could this in any way be related to the hard work done by so many men over such a long period of time in combatting the mosquito?"

We trust we will be successful in our mission of applying a great deal of information on mosquito infection rates to a continuing program of combatting *Culex tarsalis*.

Questions on Reeves Paper—

Question: Dr. Reeves mentioned infection rates in the avian species. Was this by serological methods or isolation of the virus?

Dr. Reeves: By serological methods.

Question: Does the migrant bird which spends the summer in the valley and goes south in the winter carry the virus with them to the south where it could be maintained?

Dr. Reeves: This is a point that we have discussed a great deal. The only thing I can say to this is that at the present time the viremia in these birds is limited to a very few days, and this is important for they would have to move a distance while the viremia was active to another area where a vector would pick it up and transmit it to an uninfected bird.

The question which remains, and with which we are very concerned, is whether there is such a thing as a latent virus infection in birds which would explain the prolonged infection of individuals. Although our studies are in a preliminary state, we have some rather encouraging results, although nothing that I can report in detail at this time.

In the Kern County area we do not have to *look*, with the present evidence we have, for re-introduction of the virus each summer. We know it persists there during the winter.

Dr. Meyer: The latent virus is a possibility and you can speak of a stress reaction which mobilizes the virus. We see that more and more in viruses. The jolting of a latent virus is a very interesting thing. It's even present in bacterial virus. The stress reaction comes up very vividly in all the psitticosis problems which come all the time. You can reckon with that but it is very difficult to prove experimentally. Is that not so?

Dr. Reeves: I have thought so, so far.

ADULT MOSQUITO OCCURRENCE AND HUMAN INFECTION ENCEPHALITIS CASES IN CALIFORNIA

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This subject was last discussed by this speaker at the 1953 Conference of the California Mosquito Control Association (1). Some years earlier, Dr. T. H. G. Aitken sociation. Some years earlier, Dr. T. H. G. Aitken at the 1940 Conference, reviewed the status of mos- attempted to relate these data to the occurrence of the arthropod-borne encephalitides. On the basis of information then available he concluded that "no great correlation can be made between the distribution of cases of encephalitis and the distribution of mosquitoes in California." There were valid reasons for such a statement to be made. Prior to 1940, there were only 12 mosquito control agencies in the Central Valley and little, if any, systematic attempt was made to measure mosquito populations. It should also be recalled that as of 1940 only *Aedes* species (4 of which occurred in California) had been incriminated as possible vectors of western equine encephalitis. Routine laboratory diagnostic work at that time represented but a small fraction of that now being accomplished. The Central Valley now has 24 mosquito abatement agencies which conduct a full time program of mosquito population measurement. Likewise, today we have additional vector information on certain *Culex, Culiseta* and *Anopheles* mosquitoes which occur in this state.

For the benefit of those persons present who are not well acquainted with the mosquito control program in California, it may be helpful to mention briefly the relationship of past and present mosquito population measurement programs utilized in this state.

Techniques of measuring mosquito populations in California from 1946 to 1952 were not satisfactory as aids in interpreting the epidemiology of the arthropod-borne encephalitides. During these years the lack of reliable methods of measurement and the inadequate quarterly reporting system, made it impossible to evaluate precisely and scientifically the effectiveness of mosquito control. Furthermore, these factors were partly responsible for the late start in effecting the emergency control program for the 1952 epidemic of encephalitis. At this time measurement methods were aimed primarily at the adult mosquito and involved the use of artificial resting stations, and to some extent, light traps. Since 1953 the California Mosquito Control Association has used a standardized plan for mosquito population measurement which includes consideration of both immature and adult stages. Weekly mosquito collection and occurrence reports are submitted directly to the Bureau of Vector Control, State Health Department, for recording and evaluation. Such reports include subjective larval data from field inspections and counts from light traps operating 12 hours each night of the week from March through October inclusive. Consequently, since 1953 a greater effort has been made throughout California to standardize and improve measurement techniques, in order to more fully understand the population trends of mosquitoes. Likewise, more thought is being given to the maintenance of a biological record in order to increase our knowledge of both mosquito control and the occurrence of mosquito-borne diseases.

The population trend of *Culex tarsalis* in the Great Central Valley, as measured from artificial resting stations reports during the years 1949 to 1951, exhibited two main annual peaks. Based on this three-year median, there was a moderate peak from the latter part of April through May and a higher and broader peak extending from July through September. The number of reported cases (by date of onset) of human encephalitis, calculated on a five-year median (1945-1950), reached a peak in August while confirmed cases of western equine and St. Louis reached a peak in July and September respectively. In 1952 the peak occurrence of *tarsalis* started in May and extended through July while the characteristic second peak was hardly evident. Parallel to this was the record occurrence (by date of onset) of human cases in July instead of August.

Since the occurrence and activity of *Culex* species depend, in part, on climatic conditions it may be worth while to review briefly such data. The winter of 1951-1952 played an important role in mosquito production. Heavy rains throughout the state and a record snowpack in the mountains were recorded during the winter months, December through March. These factors contributed, in part, to the early occurrence and abundance of *Culex tarsalis*. The following year, 1953, opened with an indication of a severe winter. December, 1952, was the wettest December on record in the Central Valley, but the picture changed radically during January, February and March, 1953. January temperatures were the warmest on record since 1920 with a snowpack of near zero. February precipitation was the lowest since 1899 with the greatest deficiencies occurring in the Central Valley. March precipitation fell below normal, but sub-freezing temperatures occurred through the Central Valley. This latter change in March probably contributed to the slow larval production.

The peak of adult *tarsalis*, as measured by light trap collections, occurred from August through the first of September, 1953. This closely parallels a more normal trend in the Central Valley. The peak of *tarsalis*, as measured by artificial resting station collections, occurred at approximately the same time but was considerably less than the record occurrence in 1952. The number of human cases of encephalitis was likewise much lower in 1953 than in the previous year. Only 67 percent of 34 allocated and confirmed cases occurred in the Central Valley. Fifty percent of these cases occurred subsequent to the peak of *tarsalis*. Approximately 29 percent of all confirmed cases in the state occurred in Riverside and Imperial Counties, which are located in the southeast region of California. Mosquito masurement records were available for only Riverside County. Five of the six cases allocated to that county occurred subsequent to the high peak of *tarsalis* in July.

1954 commenced with an indication of a mild winter. The precipitation in December, 1953, was the lowest since 1930 and the snowpack was below normal. January to March, 1954, evidenced near normal rainfall, normal temperatures with good frosts in the Central Valley in March and normal to above normal snowpacks in the mountains.

In 1954, *tarsalis* again exhibited a normal peak of occurrence during August and the first part of September in the Central Valley. With the exception of only a few Central Valley areas it was evident that the level of *tarsalis* occurrence was lower in 1954 than in 1953. This difference was also apparent from collection records in non-controlled mosquito areas of the Central Valley.

In contrast to this two-year difference of *tarsalis* occurrence is the three-fold increase of confirmed encephalitis cases in 1954 over those in 1953. It is significant that approximately 97 percent of these cases occurred in the Central Valley and 80 percent of the cases were allocated to the San Joaquin Counties. The remaining 20 percent were allocated to the Sacramento Valley Counties. At this time we may ask: what *was* the occurrence of the *tarsalis* population in these two regions of the Central Valley? A higher level of *tarsalis* occurrence was reported from the Sacramento Valley area, where the *tarsalis* peak occurred from the middle of July to the middle of August. This was approximately two weeks prior to the general Central Valley peak. Ninety-one percent of the confirmed cases in the Sacramento Valley Counties occurred subsequent to the peak of *tarsalis*. In the San Joaquin Valley Counties only 45 percent of the confirmed cases occurred subsequent to the *tarsalis* peak.

This review of the mosquito and encephalitis case occurrence has been presented on a very broad basis and, indeed, with reference to an extremely large area. Is the same picture true of smaller areas within the Central Valley? Four virus recovery study areas were maintained in Sutter, San Joaquin, Fresno, and Kern Counties during the summer of 1954. At the same time a mosquito population measurement program was conducted in each area. The Sutter County study area, located in the heart of the Sacramento Valley, exhibited a peak of *tarsalis* in the last week of July. Three of the four confirmed cases occurred three weeks later. The San Joaquin County study area, located 80 miles south of the Sutter County in the San Joaquin Valley, exhibited a *tarsalis* peak during the first week of August. The one St. Louis and the one western equine case detected in this study area occurred three and six weeks later. The peak of *tarsalis* occurred during the first week of September in the Fresno County Study area, while 19 of the 33 total cases (or approximately 60 percent) occurred after September first. This area is located 100 miles south of San Joaquin County. The Kern County study area, located another 100 miles south of Fresno County in the southern end of the San Joaquin Valley, exhibited the main peak of *tarsalis* during the first week of August. Ten of the 17 total cases (or approximately 60 percent) occurred thereafter.

One final question: are there other mosquito species that show a relationship to the occurrence of encephalitis cases? *Culex pipiens* and/or *Culex quinquefasciatus* show compatible occurrence with the encephalitis cases in the Central Valley. Unfortunately, we have prepared no graph for comparison with the *tarsalis* occurrence. A compilation of a majority of the Central Valley mosquito collection records showed that these species experience a similar trend through the summer months. The *Culex* species, however, continue in their prevalence through Septemper and October, a period when the *tarsalis* population is usually diminishing.

In conclusion, I believe we have made considerable progress toward understanding the occurrence of California mosquito populations. We have provided evidence which supports the belief that transmission of infectious encephalitis to man in California is principally by *Culex tarsalis*. There is still the need, however, to improve our mosquito population measurement methods, and to provide additional information on many of our other mosquitoes of public health importance.

FIELD PROBLEMS IN THE CONTROL OF *CULEX TARSALIS*

By Lloyd E. Myers, Jr., *Irrigation Engineer*
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In the light of our past experience, it is unfortunate, to put it mildly, that *Culex tarsalis* is the principal vector of the viral encephalitides we are discussing today. This mosquito is most uncooperative in its habits and has done a commendable job, from its own point of view, in creating headaches and heartaches for us. Many of the members of this group are entirely too familiar with existing *Culex tarsalis* control problems. For that and other reasons I would like to make only a brief review of some of the existing problems and would then like to discuss our prospects for *Culex tarsalis* control in the future. Unless otherwise stated, the information presented will be based upon California experience, principally in the Central Valley.

Control of disease vector mosquitoes is most efficiently carried out, ordinarily, by species sanitation programs designed to take advantage of individualistic mosquito behavior patterns. *Culex tarsalis,* however, is a most adaptable creature and has few fixed preferences or habits to assist us in developing a species sanitation program for it. Larvæ of this mosquito are found in almost any conceivable type of water collection, whether it be permanent or intermittent, shaded or unshaded, brackish or fresh, pure or foul. The female is long-lived and has a flight range which may considerably exceed two miles. Larvæ and adults have demonstrated an ability to rapidly develop extreme resistance to chlorinated hydrocarbon insecticides. Feeding and resting habits, combined with resistance to currently available residual insecticides, make adult control difficult.

The major deterrent to the development of species sanitation programs for *Culex tarsalis* is the fact that most mosquito control agencies must control noxious mosquities in addition to controlling disease vectors. Most mosquito control districts were formed to combat noxious mosquitoes and the people concerned expect and demand protection against discomfort. When an epidemic is not immediately pending, protection against discomfort frequently assumes, in the public mind, precedence over protection against disease. Many control districts do not have the resources with which to conduct completely adequate insecticidal operations against both *Culex tarsalis* and noxious mosquitoes which are principally of the *Aedes* species. Source reduction programs of most control districts have not yet progressed to the point where they can have an immediately appreciable effect on the *Culex tarsalis* population. The public must be educated concerning the facts of the comfort versus disease problem, but such education is far from easy. Mistakes in such an educational program can easily lead to near hysteria, charges of incompetence, or charges of riding a paper tiger.

Most *Culex tarsalis* sources in the Central Valley are rural and are associated with irrigation. If the tremendous load of irrigation-caused sources can be eased, mosquito control agencies will have relatively little difficulty in coping with urban sources and with non-irrigation rural sources such as sewer farms and cannery lagoons. It appears then that we should devote most of our attention to irrigation-caused sources of *Culex tarsalis.*

Rice fields are one of our toughest customers from the standpoint of applying control measures. The fields must be continuously flooded for long periods of time and we cannot drain them to prevent mosquito production. The dense rice growth hinders the use of insecticidal sprays or mosquito fish. Few, if any, districts have sufficient funds to make the repeated insecticide applications necessary for good insecticidal rice field control. Naturalistic control, however, is distinctly possible and encouraging progress is being made toward finding a satisfactory method.

When we consider irrigation-caused *Culex tarsalis* sources other than rice fields we find that this mosquito has a definite Achilles' heel. Water must ordinarily stand for a period of at least seven days before *Culex tarsalis* can make use of it to complete her aquatic cycle. This means that with only a few exceptions the production of *Culex tarsalis* is associated with waste water. Near elimination of *Culex tarsalis* breeding is not difficult in well designed and adequately maintained irrigation structures, canals and ditches. Poorly designed and poorly maintained structures, canal and ditches cause irrigation operations to be inefficient, with resulting water waste. One acre of cat-tails in a canal or ditch can transpire 15 acre-feet of water per season, or 10 acre-feet more than would evaporate from an equivalent area of canal water surface. The excess transpiration, which is total waste, represents enough water to irrigate 2½ acres of alfalfa in the Bakersfield area. Water which is allowed to run into borrow-pits or onto barren alkali land is obviously wasted. Water which stands in intermittently irrigated cropped fields long enough to permit *Culex tarsalis* production is largely wasted and damages the crop.

Some of you may wonder why I belabor the association of *Culex tarsalis* to water wastage to the point of including examples involving quantities of water which appear to be insignificant from an irrigation standpoint. We know that there are definite plans for bringing additional water to the Central Valley for agricultural use and you may wonder how, in the face of the expected deluge, anyone can forecast a decrease in water wastage. There are some aspects of the proposed projects which have received less notice than the structures involved. The insignifiicant quantities of water are becoming more significant every day.

The United States is, and has always been, a nation blessed with a surplus of water and arable land resources. It seems inconceivable to most of us that this situation could ever change. Many of our habits and practices are based on that surplus. The average United States housewife has usually had considerable quantities of food to throw in her garbage can. The average United States farmer, although remarkably efficient in using manpower, has not had to be overly concerned about conserving his soil and irrigation water.

It is expected that the population of the United States will total 190 million people by the year 1975, just twenty years from now. To furnish that population a diet based on the 1950 standard will require 577 million acres of cropland, assuming farm production efficiency of 1950. If we add to our present farmed acreage all the additional acreage it is estimated we can put into production, we will still be 70 million acres short of our requirements. If we are interested in providing an adequate diet for all of our expected population, we will be 182 million acres short. We are continually increasing our production per acre by developing new farming equipment, new tillage methods and new crop varieties, learning more about plant diseases and insect pests, and learning better ways to use fertilizers, soils, and water. But there are continually thousands of acres of land going out of production every year for various reasons such as erosion, salinity and alkali. We are not going to win the battle of production unless we make maximum use of all available resources. Limited usable water supplies are a key factor in predicted shortages.

To be more specific about future water shortages we can examine some figures for the State of California. The safe yield of presently developed California water resources is approximately 21 million acre-feet annually. The State Division of Water Resources has conducted investigations which show that present use is 24 million acre-feet annually; or 3 million acre-feet more than the safe yield. That is equivalent to drawing money from the bank without making any deposits. It cannot go on much longer. The Division estimates that 51 million acre-feet annually will be required to supply the needs of the population California expects to have by 1980. Developing the required additional 31 million acre-feet is going to take some of Harold Gray's "brain stretching" and is going to cost more than several barrels full of money. It seems reasonable to assume that when the true costs of 10 mile tunnels, 700 foot dams, 1,000 mile concrete lined canals, and 3,000 foot pump lifts are made known to the people of California, there will be a few questions asked concerning the real need for these impressive structures. Before all the planned projects are built we can be sure that there will be considerable attention devoted to the less attractive task of making more efficient use of the water resources we have already developed.

The information just presented makes it plain that the present era of water surplus and water wastage must soon come to an end, and with the end of water wastage we will see the end of our worst *Culex tarsalis* sources. Despite the encouraging outlook for the future, some control agency personnel confronted with the multifarious, frequently discouraging technical, administrative and public relations problems which have been created by the *Culex tarsalis* enigma, may find it easy to believe they have a right to take a dim view of the present. In answer to this thought I would like to point out some of the important and encouraging progress we have made in the immediate past and are making at the present time.

It has been suggested several times since this conference began that we should enlist the aid of agricultural agencies in our fight against mosquitoes. We have already made more than a good start on this. Effective cooperation has been developed between the mosquito control agencies and the University of California. Joint personnel training sessions and the bulletin "Mosquito Control on the Farm," prepared by University staff members, attest to this. The aid and cooperation of the Agricultural Extension Service has been enlisted. A research irrigation engineer from the Agricultural Research Service, U. S. D. A., participated this past summer in a joint mosquito problem investigation with Bureau of Vector Control and California Mosquito Control Association personnel. The fact that the Soil and Water Conservation Research Branch of the Agricultural Research Service has sent two research irrigation engineers to participate in this conference certainly indicates interest on the part of that agency.

We have obtained new knowledge concerning equipment and insecticides to help us with the temporary phases of our programs. Through the cooperation of the California State Health Department, the U. S. Department of Agriculture, the Kern Mosquito Abatement District, and other agencies, safe methods of using phosphate insecticides were developed and approved with amazing speed. Since that time we have learned a great deal about the use of phosphate insecticides and they have proven invaluable to some districts. Recent cooperative tests have given us important information concerning equipment for insecticide application.

We have, through cooperative investigations, begun the collection of information which is enabling us to prove that it is not necessary to produce mosquitoes in the irrigation process. When I first became associated with mosquito control, about four years ago, we had the knowledge by virtue of deductive reasoning, but we didn't have the proof. There is a tremendous difference and this new information will be of great help in obtaining the correction of irrigation-caused *Culex tarsalis* and other mosquito sources.

On a national basis, the U. S. Public Health Service and the Soil and Water Conservation Research Branch of the Agricultural Research Service have initiated a cooperative project to improve irrigation practices and reduce mosquito production in a low income area which cannot presently finance a program aimed solely at mosquito control. This project will be conducted in the Milk River Valley of Montana, an area which has severe irrigation and mosquito problems, combined with a potential encephalitis problem. Encephalitis virus recovery tests made by the U.S.P.H.S. on *Culex tarsalis* from this valley resulted in 14 isolations from 51 pools tested.

We have other important accomplishments to our credit, but there is not time to present them here. In considering our accomplishments I am reminded of a statement made by Mr. William Bollerud, Manager of the Durham Mosquito Abatement District of California. He stated, in effect, that inasmuch as mankind has been practicing irrigation for several thousands of years, and his district has been in existence for less than 40 years, he does not feel it necessary to apologize because he has not yet solved all the water use problems. I agree with Mr. Bollerud's philosophy. We have not yet solved all the problems confronting us in the control of *Culex tarsalis,* but we have made good progress. There is no need to dwell on the past. We can be proud of the present. And we can be sure that in the not too distant future *Culex tarsalis* will be a much subdued and well controlled insect.

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Dr. Meyers: I wish to thank all the members of the panel for their excellent and most interesting contributions. The meeting is adjourned.

FOURTH SESSION

1:30 P. M., TUESDAY, JANUARY 25, 1955

UNIVERSITY OF CALIFORNIA AT LOS ANGELES

The Session was presided over by Chairman Harold F. Gray, Manager, Alameda County Mosquito Abatement District, Oakland, California, in the University Religious Conference Building on the Campus. Mr. Gray was moderator for the symposium: "Mosquito Source Reduction."

Mr. R. F. Peters: This afternoon's session is entitled a symposium on "Mosquito Source Reduction." To Californians the phrase Source Reduction is synonymous with three other words, Harold Farnsworth Gray. So, with considerable prejudice in that respect, we selected Mr. Gray to make his last presentation in the harness within this subject.

Now we give you Mr. Source Reduction, Mr. Gray:

SYMPOSIUM ON "MOSQUITO SOURCE REDUCTION"

Introduction by Harold F. Gray, *Chairman*

This afternoon we are to discuss the problems of mosquito source reduction. The members of the panel are, in the order of their presentation, as follows:

1. Robert H. Peters, Manager, Northern San Joaquin County Mosquito Abatement District, Lodi, California, who will discuss the economic and legal aspects of the problem;
2. Gordon F. Smith, Technical Director, Kern Mosquito Abatement District, Bakersfield, California, who will discuss the agricultural and rural aspects;
3. Henry F. Eich, Deputy Director of Sanitation, Los Angeles City Health Department, and L. Percy Mapes, Division Foreman, Alameda County Mosquito Abatement District, Oakland, California, who will discuss the urban and industrial aspects; Mr. Eich will present the paper;
4. The presentation by Thomas D. Mulhern, Associate Vector Control Specialist, Bureau of Vector Control, California State Department of Public Health, Berkeley, California, of a sound motion picture film on mosquito source reduction procedures prepared by the Delta Mosquito Abatement District, Visalia, California, to be followed by a presentation of equipment types and uses by Mr. Mulhern.

Definite time limits have been put on each presentation, in order to permit discussion by the audience at the end of each presentation, and a general discussion at the end of the symposium. The intermediate discussions will be limited to 5 minutes and the terminal discussion to 15 minutes. We will welcome pertinent discussion.

It is hardly necessary for me to emphasize to this audience of my fellow workers and friends the position I have consistently taken over more than forty years, that the elimination or reduction of mosquito larval habitats is the essential basis of effective mosquito abatement, except in special situations. We must never lose sight of this concept. During the post-war period the impact of the so-called "miracle" insecticides caused many workers to abandon or greatly reduce their source reduction operations in favor of the initially spectacular but ephemeral insecticidal operations. But sad experience is bringing them back to the basic concept of source reduction as the *primary* method of mosquito control. While it is too much to expect of human nature that you will always "stay on the beam," I hope that you will not "get off the beam" too often in the future.

"ECONOMIC AND LEGAL ASPECTS" OF MOSQUITO SOURCE REDUCTION

ROBERT H. PETERS, *Manager*
Northern San Joaquin County Mosquito Abatement District

The economic and legal aspects of source reduction as they relate to mosquito abatement programs are indeed a vexing challenge to discussion. I must admit I have engaged in a terrific mental struggle for the past few months trying to separate the significant from the trivial on these extremely important considerations. Individually, either the economic aspects, or legal aspects are enough to invite despair, but together they really are sufficient basis for driving one to distraction.

However, the more I tried to separate the legal from the economic, the more I became aware of the wisdom of our Chairman in combining the two, since both interweave to form the fundamental basis upon which mosquito abatement programs have grown in this State. Initially, however, we should consider the historical changes which have occurred in order that proper significance can be placed on these economic and legal aspects of mosquito source reduction in relation to the evolution of our activities. Particularly should we examine and consider the legal intent and note the considerable changes that have taken place both in types of problems as well as emphasis since 1915 when our Mosquito Abatement Act was written.

Originally, mosquito abatement activities became necessary to cope with a single disease—Malaria; and to combat mosquitoes originating mostly from natural sources, particularly coastal marshes and inland swamps, which for the most part adversely affected real estate developments and necessitated a specific land reclamation approach to provide a solution.

Although these considerations are still of importance, we are now of necessity faced with a more serious disease, namely, encephalitis; and in addition must place foremost emphasis on the problems artificially created from expanded water use in our State's No. 1 economic entity—that of irrigated agriculture. Whereas at one time mosquito control could be more easily approached as a function somewhat separate from other interests, we now find our activities becoming an integral part of the total picture as agriculture affects the economy of the State. Our major problems no longer are the natural, isolated, and specific types, but rather through expanding agricultural, industrial, and domestic changes, we now find a widespread, general mosquito producing potential of far greater magnitude throughout our State. Even the emphasis on disease has correspondingly changed from a mosquito of comparatively specific origin in the case of malaria, to a mosquito of statewide concern in the case of encephalitis.

Certainly it can be indicated that mosquito control in California has become more complex through the development of the land and water resources of this State, which necessitates an objective analysis of our basic approaches and attitudes as we consider this subject.

Originally, the very word "abatement" inferred extermination and source elimination, but today the steps toward this end of necessity involve more complicated legal and economic considerations which have caused the coining of the practical term "source reduction."

The approaches or means of accomplishing source reduction are manifold, but can probably be best placed in the following categories:

1. Educational
   (a) preventive
   (b) corrective
2. Tax supported
3. Cooperative (cost basis)
4. Legal process
5. Inter-agency participation

Since it is recognized that the term "source reduction" refers to a wide scope of sources, it appears that we must broaden our outlook on this important phase of our program. Basically it appears our job is becoming one of economic justification, which pretty well guides the thinking as we consider the economic aspects of source reduction. In order to accomplish an objective one should be able to justify the end.

It is my reasoned conclusion that we have much in the way of ammunition to assist us in attempting to justify a source reduction approach in mosquito control today, and most of this ammunition has an economic significance.

Starting from our own side of the picture it is certainly logical that it is both easier and less costly in the long run to eliminate or reduce a given water source than it is to indefinitely spray such a source. Particularly is such true where we find ourselves in an expanding water use situation as is true in this State. It is also commonly known that the majority of mosquito sources become more prolific producers of mosquitoes as water remains, allowing weeds or vegetation to accumulate, thereby presenting a barrier to chemical control. Such a situation can only mean increased amounts of insecticide, increased labor, and consequently increased cost. Such, then, is our justification for directing our efforts toward mosquito source reduction.

From the other side of the picture we are obliged to approach this subject from a standpoint of attempting to point out the fact that mosquito sources are generally a waste of land and water and a failure to utilize space to economic advantage. We must preach soil conservation and water conservation in such a way that we can reach a man's pocketbook and justify a desired environmental change through cold logic, wherein we prove that our objectives only happen to be the same as those of a party who has failed to realize the greatest possible economic advantage from his land. If a pasture, for example, is over-irrigated so that twenty percent of the field is producing mosquitoes, that portion is not, or soon will not be growing the clover or grasses that were planted originally. Economically, this means that this farmer is operating at only 80 percent efficiency and is realizing one-fifth less return than would be possible if all the field were producing. If he has a pump, he is not only wasting water, but is paying an electric bill considerably in excess of that which is necessary.

If a cannery, winery or sewage plant is flooding twenty acres with waste water when ten acres, if adequately prepared, could hold the water, then there is a failure to utilize land which might be put to better use or leased for more than enough to prepare a system to dispose of the wastes in an orderly manner.

Often it can be pointed out that continuous or eventual maintenance costs are in excess of orderly, organized waste water management either in industry or agriculture.

In the agricultural field of source reduction, we have been greatly aided by a recent Agricultural Extension

Service publication, "Mosquito Control on the Farm," by Bailey, Bohart & Booher, wherein the following point is emphatically made:

> "Water which stands on fields for more than 24 hours after irrigation is of no benefit to crops, except in such specialized operations as rice growing."

This point is extremely important in support of our mosquito source reduction objectives.

We are fortunate indeed to be in a position that finds our aims allied so closely with good agricultural practices as pertains to water use, and it is our job to utilize this coincidence to our mutual advantage.

My experience in the field indicates that none of our objectives are inconsistent with good water management. It is, therefore, only reasonable that we should proceed actively and intelligently toward an expanded source reduction approach in our programs if we are to ever keep pace with, let alone equalize, these water sources which are increasing daily.

For specific justification of the source reduction approach I would like to point out some rather convincing conclusions which our District has realized in our own program.

Of greatest significance to our total effort has been our source reduction program along the Mokelumne River bottom where over a period of several years we have materially altered the entire emphasis of our program through this approach. We have changed the problem rating of this area from first of importance to about fourth at the present time. This phase of our program has been based on removing the jungle-covered sources of three species of *Aedes* mosquitoes with heavy equipment, by leveling and leveeing these lands to where these species of mosquitoes have been reduced from a population of billions to where they are now rarities. Economically, our results to date have had a marked effect on our total cost of control. From the standpoint of insecticide use alone, there has been a distinct downward trend over the past four years as follows:

1950	3,828 lbs. DDT
1951	2,017 lbs. DDT
1952	2,111 lbs. DDT
1953	726 lbs. DDT
1954	531 lbs. DDT

This is a reduction to 1/7 of the amount of initial insecticide used in this period, and, of course, we all know that the corresponding reduction in labor costs is where the real savings can be realized.

The positive effect can be best summed up, however, in the realization that we have now made approximately 800 acres of river bottom land usable for agriculture, industry and recreation. Approximately 100 acres of industrial waste ponds have been built or reconstructed into orderly, accessible, functionable disposal beds. This represents a reduction in space to about 2/3 of the original unorganized, inaccessible area, and a consequent reduction of control costs to about one-fourth of the original total.

Agricultural crops of tomatoes, beans, corn and pastures now replace the inaccessible jungles in this changing landscape at a cost averaging around $120.00 per acre to the farmer.

Although our strides in solving some of the agricultural sources in other areas of our District have not been as rapid, the following source reduction efforts show a trend based on similar justification. A series of drains on one farm of approximately 100 acres resulted in the reclaiming of about fifteen acres of additional pasture for the farmer at a cost of about $33.00 per acre. A definite reduction in insecticide to 1/3 the amount and total manhours to 1/6 followed this effort during the ensuing year.

In another instance where 400 acres of wild pasture was flooded about ten times yearly, a system of drains was installed to reclaim about fifty acres which previously remained under water. This effort reduced our control costs from around $1200 to less than $400 the following year.

Another community project recently completed now drains three farms of about 110 acres into an artificial lake from which one farmer can reclaim the water by pumping into his irrigation system. About fifteen additional acres are now available for grazing, and our costs of control were reduced to one-fifth of the previous year.

In all of these jobs our approach has been one of selling the idea to the farmer, or principal, that he is losing money by allowing conditions to exist where he is not utilizing his land which, incidentally, is also producing mosquitoes. This approach has been consistent with our belief that mosquito considerations are becoming secondary to major factors of space utilization and water use, and should not, therefore, be the legal basis for environmental change, at least until such time as no progress can be made through the process of reason and economic justification.

Certainly at this time there arises a need for consideration of the legal aspects of source reduction.

The following sections found in Chapter 5, of the Health and Safety Code, Article 4, under "District Powers," appear to guide our present source reduction approaches.

"Sec. 2270 (a) Take all necessary or proper steps for the *extermination* of mosquitoes, flies or other insects . . .

"Sec. 2270 (d) If necessary or proper in the furtherance of the objects of this chapter, build, construct, repair and maintain, necessary dikes, levees, cuts, canals, or ditches upon any land, and acquire by purchase, condemnation, or by other lawful means, in the name of the District, any lands, right-of-way, easements, property, or material necessary for any of those purposes.

"Sec. 2270 (j) Do any and all things necessary or incident to the powers granted by, and to carry out the objects specified in, this chapter."

In the abatement procedure, Section 2276 implies environmental change wherein it states, "The notice shall further direct that the owner shall, within a specified time, perform any work which may be necessary to prevent the recurrence of breeding in the places specified in the notice." In Section 2282 it further states that the district board shall take appropriate measures to prevent the recurrence of further breeding, where a notice to abate is not complied with.

Although it is recognized that the above may be construed to justify legal actions to accomplish source reduction, we also should note that considerable change has occurred in our administrative procedure, as well as our concepts, since 1915 when this law was written.

In the interest of comparison it should be recognized that the law originally provided for *extermination* and *elimination* of mosquito sources by abatement through legal process conducted by a Board of Trustees of which the Secretary appeared to be the key member. However, in recent years changes in our agricultural, industrial, and domestic pattern, through an expanded water use, have resulted in a new set of conditions. We now find ourselves carrying on programs emphasizing an administrative approach based on technical assistance and cooperative services, wherein our Board of Trustees are accomplishing their objectives indirectly.

Today we have almost stopped thinking of extermination and elimination as practical terms and instead find ourselves thinking in terms of "control" and "minimization" as they apply to our changing expanded problems.

It is my firm conviction that in our future outlook, wherein we find our functions directly affecting the public economy as never before, we must collectively use wisdom in resorting to legal procedures to accomplish source reduction, since laws like mosquito sources can be changed to best suit the public interest.

Can we any longer consider our law as the sword of our future? Can we any longer consider mosquito occurrence as a public nuisance in the same general sense as we have in the past?

Are we not, instead, developing into highly trained and skilled agencies which will even more utilize the positive approach in the future through education, professional services, and proper equipment to assist our constituents in developing the land and water resources of our State?

AGRICULTURAL ASPECTS OF MOSQUITO SOURCE REDUCTION

GORDON F. SMITH, *Technical Director*
Kern Mosquito Abatement District

For many years the by-word of those mosquito abatement districts concerned primarily with agricultural problems in California has been that by far the greater portion of mosquito production due to agriculture is the result of the excessive use of irrigation water. In recent years, as difficulties with insecticides increase, this statement is heard plaintively, in explanation, or belligerently, but ever more often. It is a very nice, pat statement, and I think it may be easily defined as "water applied to the land in excess of that needed for the best production of the crop at hand." That is a simple definition and probably very inadequate; however, there is a joker in the deck, and that is the word "excess." Considering all the phases of the subject at hand, there doesn't seem to be any easy definition of the word excess. In fact, it may have to be redefined with each individual case where mosquito breeding occurs.

Since the needs of agriculture are the primary factors concerned, and mosquito control is actually of secondary importance in the economy, the procedures selected for the handling of a mosquito source on any piece of agricultural land should not interfere with, and if possible, should enhance the productivity of that land. It must fit in with the economy of the area in general. It is, therefore, necessary, in considering mosquito source reduction in agricultural areas, to look carefully into each problem, and, taking each on its own merits, to determine what can be done to eliminate the source or to reduce it to the point where it may be controlled with the greatest possible economy. In so doing there are a number of factors which must come under consideration. Although these factors are more easily considered separately, they are, in the final analysis of the situation, interacting and variable from year to year.

The preparation of the land is, of course, of first importance. Is the land leveled, without low spots, and of proper slope for the soil involved? Too great a slope will mean that a great deal of water must be run through a field in order to get penetration in tight soil, and too little slope may mean ponding. Also, the land once leveled will not necessarily remain so; and good farming must include periodic land planing and releveling in long range plans. Some farmers land plane yearly.

Since mosquitoes are produced only when water remains on the surface of the soil for a period of time, the permeability of the soil is of prime importance. The farmer wants the water to penetrate into the soil to be available to the plants, and we want it to penetrate into the soil so that it will not produce mosquitoes.

Often much can be done to "open a soil up" so that water will penetrate. In the case of alkalies, they must be leached down out of the root zone. This leaching often requires considerable quantities of water, and some mosquito production will result for a period of time. Chemical additives are commonly used to aid and speed this process. Mechanical adjuncts, as deep chiseling and the planting of deep-rooted crops, are also very helpful in many cases to speed leaching and to open up the soil to percolation. Under these conditions it is of little value to require a farmer to put in an expensive drainage system which will not be needed in a few years; although it is often possible to reduce the source by some relatively inexpensive means, such as draining into a natural slough, which would not be satisfactory as a permanent measure, but will ease the situation until the land is in such shape that proper permanent drainage measures may be planned if necessary.

The compaction of soil is another thing that leads to mosquito production, and the damage to the soil is often not realized by the farmer. The best way to eliminate this seems to be by prevention, by keeping equipment or cattle off of the moist ground. Occasionally some good can be done by chiseling or ripping to break up the compacted layer.

The stage of growth and nature of the crops planted in a field will also have a considerable amount of effect on the mosquito production on a given field. Young crops, especially if cultivated, will rarely cause a mosquito problem when properly irrigated, as they do not require a great deal of water. However, as they mature they will require water more frequently if shallow-rooted, or in greater quantities if deep-rooted in order to make optimum growth. Problems will often develop toward the end of the growing season. Irrigated cotton is a good example. In the Bakersfield area, there is almost no problem in a cotton field itself during the early part of the season if the field is properly leveled. However, as the plants grow larger, the root system reaches a greater depth; the water demand of the plant increases; and the farmer ceases cultivation, thus allowing the surface layers of soil to seal and making it harder to get water penetration into the soil. The farmer then has to irrigate more heavily in order to get water through the soil surface and into the soil throughout the root zone of the plants. The inevitable results. In cases I have seen, seemingly adequate tail water return systems, installed with every intent to eliminate this problem, and which would normally be sufficient for any other crop, could not cope with the water used on cotton at the peak of the season.

Therefore, if possible, plans should be made to eliminate the problems expected from the crops using the greatest amount of water during any period of time. However, sometimes it may be unreasonable to ask this if in a rotation system only one crop will cause any great problem, and then only for a short period.

Permanent pasture and cattle undoubtedly cause a greater problem than any other in the Central Valley. This is in part due to the fact that permanent pasture is often put on soil unsuitable for most other crops due to its lack of permeability, high water tables, shallow hard pan underlie, etc. All too often, permanent pasture is considered permanent *ad infinitum*. Cattle often are not removed during irrigation or are allowed on the land while it is still wet, compacting the soil and causing depressions which hold water long enough for mosquito breeding to take place. These latter practices also are highly detrimental to the growth of desirable pasture plants. Although the low ends of such pastures can be drained, there is often little that can be done about the pot holes in the field except to relevel and replant the pasture or rotate its crops.

Irrigation practices and procedures are often subject to modification which will tend to decrease or eliminate problems. Excessively long and wide checks are often trouble makers. Farmers may feel that irrigation can be accomplished more rapidly with one-half to one mile checks, but it is extremely difficult to control the water over such a distance.

The availablity of water and the condition of the water table often are considerations in talking to a farmer. Where water must be pumped from a considerable depth, it becomes a very valuable commodity, and anything done to reduce wastage or reclaim that which may otherwise be wasted is money in the pocket. In the case of a high water table, it is always to the farmer's advantage to put on a minimum of water to prevent further rise in the water table. Too high a water table will interfere with proper root development of many plants and also will leach alkali toward the root zone of the crops.

Local practices and prejudices, no matter how invalid, are factors which always must be taken into consideration. To attempt to butt headlong into a widely established practice may do more harm than good. It is generally far better to use education and persuasion though it may take considerable time. The financial situation of the farmer involved is always a consideration in discussing what should be done and how long it may take. It is not difficult to put up with a problem when a definite program of progressive improvement is agreed upon. Last but not least, and perhaps the less said the better, the personality of both the farmer and the mosquito abatement personnel have much to do with the accomplishment.

In the final analysis of the problem, the first thing is to attempt to put the water in the right place at the right time, in the right manner, and in the right amounts. If this could always be done, there would be no agricultural mosquito problem. However, there is often much that can be done over a period of time to improve the situation through better land management and through more progressive irrigation practices with more careful water handling.

Nevertheless, there will be many cases where excess water will be present, either through necessity or due to the fact that irrigation is not an exact science. The problem remains of how to handle this excess as economically as possible and so that it will cause a minimum mosquito problem. In areas of water shortages or high water cost, it is only logical, where development of the land is already completed, to attempt to reclaim this water as a measure for economy and water conservation. In many cases this can be accomplished simply by picking up the excess water in a ditch at the low end of one field and carrying it by gravity to the upper end of another field for use.

In many cases, especially when irrigating with pipelines, it is necessary to drain the excess water to a sump and pump it back into the irrigation lines. Although this type of installation will sometimes be expensive, the benefit to the farmer is unquestionable and the cost can be written off the taxes over a period of years. This procedure also reclaims the fertilizers and soil amendments which often are applied with the irrigation stream.

In many cases the cost and availability of the water may be such that the cost of a return system does not seem justified. Also, even in water shortage areas, on newly developed land, it may be felt that the tail water carries dissolved minerals which would be detrimental to the land if returned. In these cases it may be possible to confine the excess water in seepage or evaporating basins, either completely excavated or constructed in a natural slough or depression. If you are lucky, drainage can be made to a flowing stream or to a point where it can be pumped into an irrigation canal or ditch without too great a cost.

In areas with a high water table, it seems to me that return systems may at times be useful in lessening the total amount of water applied to a field. Wells to draw water from the high water table and expel it into drainage works also are useful, and sometimes underground drainage systems may be needed to keep the water table below the root zone of the crops.

Once all has been done for the land that is reasonable and drainage works have been installed, the problem is still not solved. Proper maintenance cannot be over-emphasized. Fields once leveled must be kept in shape. A ditch and sump so heavily overgrown as to prevent the use of insecticides or natural predators may present a worse mosquito problem than the water lying at the end of a field.

A good source reduction program and good agricultural practices should, must, and will go hand in hand, providing that the problems of both the farmer and the mosquito abatement district are well understood and that patience and good planning are used.

URBAN AND INDUSTRIAL ASPECTS OF MOSQUITO SOURCE REDUCTION

H. F. Eich and L. P. Mapes

If a mosquito abatement agency in a local government is to continuously accomplish any significant reduction in mosquito habitats in any urban area, the following precepts must be followed:

(1) Close cooperation and support of all affected Departments of the local government, State and Federal agencies.
(2) Assignment of responsibility to private property owners for mosquito control on their premises where municipal legislation is possible.
(3) Intensified public education.

Urban mosquito control as contrasted to rural control involves a multitude of dissimilar sources which may be impossible of adequate regulation were it not for the existence of large responsibilities binding upon property owners to satisfactorily control breeding on their property, supplemented by adequate inspection services and a continuing public information program. Rain barrels, service station tube immersion tanks, backyard fish ponds, and lagoons from industries are examples of habitats which create problems if the owners are not acquainted with indications of breeding and control measures. Some cities may have irrigation and drainage problems in essentially rural peripheral areas, requiring these land owners to systematically control or eliminate breeding.

An urban program requires dependency upon other departments for the actual improvements in source reduction. Improved design of drainage structures prevents the creation of habitats which from our experience would require many man-hours for treatment. This phase of the program extends to storm channels, drains, catch basins, streets and ditches. Involved, therefore, are the City Engineer, in some cases the Corps of Engineers, and the County flood control agency. The proper maintenance, alteration, and repair of these facilities can relieve a mosquito control organization from a great amount of work. Unimproved streets are notorious sources of mosquito breeding in the city of Los Angeles. Depressions, flat paved streets, and deteriorated paving can give rise to additional problems.

Preventive Program Through Proper Design

In the City of Los Angeles there is an advisory committee to the Health Department consisting of developers and engineers engaged in subdivision work. These men consider all policy matters affecting the sanitation of subdivisions, which includes the disposal of sewage and mosquito control. Through this group it has been possible by illustrated talks, by the preparation of comprehensive maps, and by working in cooperation with the City Engineer's office on subdivision matters to achieve satisfactory drainage wherever the subdivider can reasonably conduct tract drainage to a proper receiving point. This may be realized by a paved shoulder or roadway ditch to carry surface waters to a nearby paved street or, in some cases, by means of a paved ditch draining the tract into a storm channel. All subdivisions in Los Angeles must be developed complete with street paving and curbing and surface drainage properly conducted to a dedicated street off the tract. In many instances, however, this dedicated street is not paved, with the result that sources of breeding will develop if no paved ditch, storm sewer or equivalent is provided to carry this water to a more acceptable point.

The Corps of Engineers in a project which is now under construction involving several miles of paving of the Los Angeles River did, before the job was actually designed, request recommendations of the Los Angeles City Health Department. In this particular instance it was pointed out that a need existed for a small central channel to carry dry weather flow (which is continuous and sizeable), since a wide flat bottom results in silt accumulations, pockets and weed growths and subsequent breeding. Although the design office did not originally appear to be in favor of this more costly type of construction, the paving thus far completed does include this small central channel.

The office of the City Engineer responsible for storm drain design is fully acquainted with the Los Angeles City Mosquito Control staff's desires insofar as rapid and complete drainage of structures is concerned, and does follow a design which incorporates into each ditch, drain box culvert, or similar facility a pitch to the center which has satisfactorily prevented any flat portions where ponding may occur.

From experience it has been observed that a paved shoulder, whether it be in the form of a rolled asphalt curb, a "V" type asphalt curb, or the conventional concrete curb, may provide adequate control against mosquito breeding which would ordinarily occur in the soil adjacent to a paved roadway. The Los Angeles City Engineer's office has agreed to provide such paving in all instances where the city does the work on widening or repair of roadways, and they require similar paving on subdivision or other developments which they supervise. This has not only eliminated many habitats but also has prevented many others that would have been produced if this type of paving had not been required.

The Elimination of Breeding Sources From Existing Facilities and Properties

The Street Maintenance Division in the City of Los Angeles has cooperated in a fine manner in the reduction of the overall problem of drainage correction on unimproved streets. Their scrapers and other power equipment have kept the sides of these unimproved streets reasonably clear of weeds and properly drained whenever it was possible to do so. In some instances, additional soil was brought in to fill up depressions, or ditches were constructed over unused but dedicated streets which receive drainage from adjoining subdivisions. In many instances, however, no solution short of actual paving will eliminate the sources. This type of problem still remains over approximately forty miles of unimproved streets in Los Angeles. It will continue and undoubtedly increase in view of the present rate of subdivision in the area.

Relatively large bodies of water which may continually contain water, and which may also have considerable weed growth, may effectively, and over a long period of time, be controlled by stocking with *Gambusia affinis*. This has proven successful in large debris basins receiving storm waters in the vicinity of reservoirs, and in the unpaved portions of storm drain channels.

The Corps of Engineers has annually brought bulldozers and other power equipment into the unpaved portions of the Los Angeles River to provide a single central channel. This has eliminated all side pockets and small branch channels which otherwise would prevail. Control work along the river is particularly difficult when this type of maintenance is not continually provided, since the large boulders and excessive weed growth require that control measures be accomplished by hand sprayers.

Catch basins in the past have been so designed that water would remain in the bottom. These require routine spraying either by the control agency or by the storm drain maintenance organization. Street inlets or catch basins now are usually designed so that water is no longer maintained in the bottom.

Underground street vaults of the public utilities which are not properly drained have produced problems in Alameda County. However, DDT residual sprays have provided satisfactory control, although a satisfactory drain is the preferred solution.

Cemeteries are evidently a nationally encountered source of breeding due to the flower containers installed at each grave. A 5 percent aqueous spray using a blower has been used on three-week intervals during the summer for control in Alameda County, while in Los Angeles containers are required to be periodically inverted. A better and more economical solution to this problem is to be desired either through a change in design or operation.

Holes in trees are a prolific source of the tree-hole mosquito *Aedes varipalpus*. Tree surgery is the recommended method of correction, although Alameda County has found filling with a 1:7 cement-sand mixture to be effective. Where this occurs in parks, the local park departments can remove the source by corrective measures by their own crews.

INDUSTRIAL PROBLEMS

One of the principal sources found in private premises is the uncovered or improperly covered water tanks. These may be found in conjunction with all types of industries, railroads, or in some cases residential buildings. Screening or other covering may be used to prevent breeding, or where the water is not used for domestic purposes, routine spraying either by the owner or the control agency may be utilized.

One example of a similar problem may be found at nurseries, particularly those handling tropical plants where tanks necessary for the heating and distribution of waters and for the preparation of fertilizers are used.

Another instance is in the pickle industry where the large vats used in the curing of cucumbers must be kept filled with water when not in use to prevent the development of leaks. This has been a sizeable source in the past, and the proper solution is still under study. Various proposals including paraffine seals, mineral oil, heavy brine water, and even the use of *Gambusia affinis* have been tried. Olive packing plants have similar problems which can produce excessive breeding.

Liquid wastes from breweries, orange juice extraction, or any industry producing large quantities of waste cooling waters will always present serious problems unless suitable receiving facilities are available to carry these wastes to a point of proper disposal. Where a legal requirement for self control is available, sewer connections or paved ditches to receiving channels can provide the solution which will relieve the mosquito abatement agency from costly repetitive treatment.

DWELLINGS

At single-family residences perhaps the principal sources of mosquito breeding are private sewage disposal systems, fish ponds, and defective plumbing. The old cesspool is by far the most important and the most troublesome. Hillside developments in Oakland experience seepage problems from septic tank systems, sometimes converging in street gutters. Occasionally broken or defective plumbing create accumulations of liquid under buildings. Here the cooperation of the plumbing inspection department is helpful. Education of the public can do much to reduce the volume of work that can develop, particularly in areas which are to a great degree developed with homes served by private sewage disposal systems. With regard to the fish ponds, considerable success has been achieved in Los Angeles by the annual distribution of *Gambusia affinis* fish for use by individuals having fish ponds or small lakes.

(Editor's note: Following a sound film on mosquito source reduction procedures, a presentation on "Equipment Types and Uses" was given by THOMAS D. MULHERN, *Bureau of Vector Control, California State Department of Public Health, Berkeley, and was based upon slides shown at the session; hence, no paper was submitted for publication.)*

BUSINESS MEETING OF THE CALIFORNIA MOSQUITO CONTROL ASSOCIATION, INC.

8:00 P.M., TUESDAY, JANUARY 25, 1955

ST. LOUIS ROOM, HOTEL STATLER

President Grant: Will the meeting please come to order. We want to start off first by getting a list of the representatives of the corporate members of the CMCA who are here. Will Ed Washburn please read off the list?

I've served as president for a little over a year and have been very happy over much of the business which has transpired. It certainly has been a busy year; having had seven California Mosquito Control Association Board Meetings. We've had a relatively successful year as far as mosquito abatement goes; I hope it hasn't all been due to the weather. Much of this year has been spent in establishing aims and policies, standardizing procedures, etc., which we have been looking toward for the past many years. We have seen one new district formed this year, the San Joaquin Mosquito Abatement District, and we see no particular decrease in mosquito problems, unfortunately. It all points to more growth in mosquito work.

We have suffered the unfortunate loss of losing Harold Gray through retirement, one of our most active members. I'm sure we haven't lost him entirely. (Gray, in audience —"I'm not lost yet"). We have tried to help out the constitutional function of this Association in getting information to members and agencies by the Forms, Records and Statistics Committee.

We have developed many progressive concepts; many of them haven't materialized yet, but we are working on those. I hope I'll see their completion sooner or later.

I am very much indebted and very grateful for the many contributions of all members of the Association. The cooperation I've had during this term of office has been grand; to all the committee chairmen and to the Secretary, who has been hard put to get out the notices, minutes, and so forth, and to the members of the Conference Committee, who have been doing a very wonderful job that has made it so successful thus far; to all of you, I extent my thanks.

The next point of business will be the committee reports of Standing Committees. First I'd like to call on Ed Washburn for the Treasurer's Report.

REPORT OF THE SECRETARY-TREASURER DECEMBER 1, 1953—DECEMBER 31, 1954

Annual Conference
January 23-27, 1955
Hotel Statler
Los Angeles, California

Gentlemen:

Herewith is submitted the report of the Secretary-Treasurer and the Financial Report of this Association for the period December 1, 1953 to December 31, 1954, inclusive.

It will be noted that this period is greater than one year. The report also reflects certain incomes and expenses of the 21st, 22nd, and 23rd Annual Conferences. Hereafter, this report for the Annual Meetings will be made for a calendar year of January 1 to December 31 only, and not for a conference year, unless this office is otherwise instructed by the Board of Directors.

A financial statement was circulated to the membership covering the first six months of the calendar year just completed. It is incorporated in this report.

It will be noted that expenditures made during the period reported were many and often large. If this is continued at the same rate, the treasury will soon be depleted.

It is my recommendation that the Board of Directors carefully weigh and consider any large demands upon the treasury this coming year. I also recommend that no expenses be incurred or paid by this Board of Directors without authorization of the same.

I believe that it would be well if the Auditing Committee actually audits the books and records as they are kept in the office of the Secretary-Treasurer. This would better insure that they are being kept in the manner desired. It also would afford an opportunity for changes in bettering the records.

Respectfully submitted,
G. Edwin Washburn
Secretary-Treasurer

FINANCIAL STATEMENT
CALIFORNIA MOSQUITO CONTROL ASSOCIATION, INC.
December 1, 1953—December 31, 1954

Income and Receipts:		
Balance on hand December 1, 1953 (22nd Conference)		$ 5,315.96
Income:		
Contractual dues	$2,825.00	
Associate member dues	138.00	
Sustaining member dues	475.00	
Publication sales (Proceedings)	80.00	
Decal sales	17.40	
Registration fees (22nd Conference)	123.75	
22nd Conference income (reg. booth, etc.)	1,038.07	
Income Total		4,697.22
Total Receipts		$10,013.18

Expenditures:	
Printing, 22nd Proceedings (850)	$ 1,487.50
Express charges (22nd Proceedings)	9.30
Stenographic service (22nd Proceedings)	203.00
Program printing (22nd Proceedings)	77.77
Conference Costs 22nd (Hotel Claremont, etc.)	1,288.59
Stationery	123.55
Postage	130.52
State Fair Booth	485.33
Recorder repair and tapes	60.96
Associate member certificates	55.26
Herms Award (Two years)	95.00
Travel (Dr. A. W. A. Brown)	302.15
Travel to AMCA—½ of costs	407.64
Telephone	33.65
Mosquito News (½-page ad)	108.00
File cabinet (5 drawer)	116.56
Margaret Prefontaine (For services)	100.00
Rubber stamp	2.33
Refund on one copy (21st Proceedings)	2.50
Conference advance (23rd)	200.00
Ernest R. Geddes (Conference expenses)	71.00
Total Expenses	$ 5,360.61

Recap:	
Total receipts	$10,013.18
Total expenditures	5,360.61
Balance, December 31, 1954	$ 4,652.57

INVENTORY OF CMCA PROPERTY
DECEMBER 31, 1954

Gentlemen:

It was the recommendation of the Auditing Committee of the 22nd Annual Meeting, and duly accepted by the membership, that an inventory be made of the supplies and equipment belonging to this Association. Accordingly, this was done on the above date.

The attached inventory of property owned by the CMCA is all located in the office of the Secretary-Treasurer at the Turlock Mosquito Abatement District, Turlock, California.

I have purposely not given a value to the items listed, since many of them cost the Association nothing, and have doubtful value today. Certain items are in the nature of Capital Expenditures and, of course, have real value.

No listing has been made by this office of any equipment or supplies which are being used in the Operational Investigations program. Legal opinion (on record) has stated that legally all such equipment, etc. is owned by the Agency through which it was purchased. In the interests of future developments it may be well to explore the possibility of this equipment being given or sold to the CMCA for a nominal price. It cannot be legally accomplished except by adoption of a resolution so stating, by the mosquito abatement district Board of Trustees concerned.

Respectfully,
Secretary-Treasurer
G. Edwin Washburn

Inventory of CMCA Property

1. 1 5-drawer file cabinet
2. 1 Eicor tape recorder
3. 10 Plastic sound recording tapes
4. 14 Paper sound recording tapes
5. 1 25-foot extension jack for recorder mike
6. 1 Sectional post-binder (account book)
7. 1 3-inch CMCA cut
8. 2 1-inch CMCA cuts
9. 1 Rubber stamp (CMCA address)
10. 900 CMCA Decals
11. 2500 Envelopes
12. 777 Prof. Herms Lithograph pictures
13. 1 State Fair Plaque
14. 77 16th Proceedings
15. 219 17th Proceedings
16. 35 18th Proceedings
17. 280 19th Proceedings
18. 41 20th Proceedings
19. 251 21st Proceedings
20. 365 22nd Proceedings

Miscellaneous Materials:
State Fair booth cards, maps, drawings, etc.
Operational Manual page sets

Compiled by

G. Edwin Washburn
Secretary-Treasurer

Mr. Grant: You've heard the report; what are your wishes regarding it?

Mr. Gray: I move we accept the report. (Seconded by Sperbeck; voted acceptance of report by oral vote.)

Mr. Grant: Do you wish to take any action in regard to the recommendations in the report?

Mr. Gray: I move they be referred to the Executive Committee for action. (Seconded and duly passed.)

Mr. McFarland: In referring to the recommendation of bonding the treasurer, I believe that is an oversight which should not happen. However, there is another person who probably should be bonded; the finance chairman of the conference committee. Each year he handles large sums of money in the name of the Association, usually some $3,000 to $4,000. I believe the Executive Committee should include bonding of the finance chairman in order to protect the Association. I move this be done. (Seconded and duly passed.)

Mr. Grant: You heard the report on the inventory; what are the wishes of the Board regarding this material? This is not a committee report, but an addendum of the Secretary-Treasurer's report.

Mr. Washburn: I might make a remark in regard to the inventory. If you give a total value to the Proceedings that we have on hand, the Proceedings are now valued at $2.50 each, or a total of $3,269.50. The total value of equipment the Association owns, including Proceedings, is $4,468.78. The thought has occurred to me that should we have a fire in our particular office (Turlock Mosquito Abatement District) this material would be lost, and it is not covered by our District insurance. Of course, all records, all proceedings, etc., except what you have in your offices would be destroyed. The place is given about 5 minutes if a fire has a good start.

Mr. Grant: Possibly the personal items, files, etc., which you have should be put on an inventory. There is no question about the ownership there, or is there? Perhaps a list of these could be supplied to Don Murray of the Records, Forms, and Statistics Committee, while the other material, which is in an undecided status, would not necessarily be included in the Yearbook at the present time. The valuable papers should be stored in a fireproof place. (No action taken). I would like to go on at this point to the reports of the committees. I'll call on Robert H. Peters, Chairman of the Education and Public Relations Committee.

REPORT OF THE EDUCATION AND PUBLIC RELATIONS COMMITTEE

As Chairman of the Education and Public Relations Committee, I can briefly sum up the activities of this committee as follows:

1. An effort was made through correspondence to arrange for a commercial film on mosquito abatement activities in California. Unfortunately, the high cost and varied opinions on film content and scope apparently made the basis for further negotiation somewhat unlikely.
2. A booth at the California State Fair was constructed by a sub-committee headed by George Umberger. This effort was favorably received by the huge throng which attends the State Fair annually, and should be given consideration during the 1955 Fair.
3. An educational type booth has been constructed for our joint conference through a sub-committee headed by Edgar Smith. I'm sure this booth is worthy of everyone's attention and should be visited by all in attendance.

Robert H. Peters, *Chairman*
Education and Public
Relations Committee

REPORT OF THE MEMBERSHIP COMMITTEE

The California Mosquito Control Association, to date, includes forty-seven (47) Associate Members, 26 Sustaining or Contributors, and one Honorary Membership. The Corporate Membership will be discussed in the report of the Secretary-Treasurer.

The following recommendations were submitted to the Board of Directors on July 7, 1954, and were approved as of that date.

1. That a "Renewal Dues Form" be developed to facilitate the billing of current members in the Association.
2. That the mailing address on the Associate Application form be changed to correspond with the address of the Committee Chairman.

Additional recommendations are herewith presented for consideration by the succeeding chairman of this Committee.

1. That the Secretary-Treasurer be given a listing of the Associate Members with their mailing addresses, and that the Secretary-Treasurer be directed to mail to each member information deemed to be of general interest to the entire Membership.
2. That a standard of procedure be developed for soliciting membership to the California Mosquito Control Association.

Howard R. Greenfield, *Chairman*
Norman R. Ehmann
Gordon F. Smith
William L. Rusconi
Ernest E. Lusk

REPORT OF THE WAYS AND MEANS COMMITTEE

The Ways and Means Committee presented an interim report to the Board of Directors at their meeting of November 5, 1954 in Modesto, California. In this report the following recommendations were made:

1. That it would be highly desirable to establish a centralized point of origin for news releases of general interest on mosquitoes and mosquito control. Copies of such releases should be sent to local agencies in advance of release date to make possible contact with local newspapers for a local angle to the stories. It was felt that this would be a logical service of the Bureau of Vector Control.

2. That better coordination be developed in the dissemination of information to all agencies of current operational techniques developed in individual districts. Since information concerning successful practices in individual districts is sometimes slow in filtering out, it was felt that some method should be devised to speed up this process. It was further recommended that Bureau of Vector Control personnel during the normal course of their duties might be in the best position to help in this matter.

3. It was further recommended that the Ways and Means Committee together with the Legislative Committee should develop definite recommendations in the form of a legislative bill amending the Health and Safety Code

establishing an organization similar to the Conference of Local Health Officers.

Since that meeting, the Bureau of Vector Control of the State Health Department has taken definite steps to accomplish the recommendations of the Ways and Means Committee in regard to Points No. 1 and 2. The Board of Directors of the California Mosquito Control Association charged the Ways and Means Committee with the responsibility of working with the Legislative Committee to develop positive recommendations in regard to the formation of a somewhat different type of organization of local mosquito contol agencies. Such organization should be established by statute to include all full time mosquito abatement agencies and to establish an advisory relationship with the State Department of Public Health. The two committees have held several meetings and have come to agreement on such a legislative bill. Full particulars were mailed to all member agencies of the California Mosquito Control Associations on December 29, 1954.

The Ways and Means Committee recommends approval of this proposal by the California Mosquito Control Association.

Respectfully submitted
Ways and Means Committee
Edgar A. Smith, *Chairman*
John O. Stivers
Jack H. Kimball
Ted Aarons
Ted Raley
Gordon Smith

REPORT OF THE COMMITTEE ON FORMS, RECORDS, AND STATISTICS

This Committee assembled from the various mosquito abatement agencies an assortment of information which has been used for a number of purposes.

Two major projects necessitating that questionnaires be sent to all mosquito abatement agencies have been or will be completed. The first, in the spring of 1954, was a salary schedule, plus general employee information. This helped many districts analyze their programs in comparison with the programs of other districts, undoubtedly resulting in benefits to some employees. Several requests for extra copies of the report, for presentation to individual board members, were received.

The second major project was the development of the CMCA Yearbook. While the information in the employee salary report is available to the general public on request, several managers expressed the opinion that circulation of that report should be restricted to mosquito abatement agencies only. The Yearbook, on the other hand, supplies interesting and important information of a broad scope for wide circulation. Inasmuch as time did not permit assembling of material for the Yearbook at an earlier date, it was decided to print the report as soon as possible after the Los Angeles Conference, so that the information will be up to date for the longest possible time.

Three projects of a relatively minor nature also were handled by this Committee:

(1) Questionnaire on aerosol machine use, for submission to Dr. A. W. A. Brown, who spent a part of the summer testing aerosol machines of diverse types in the Merced area.

(2) Questionnaire requesting estimates from each District of the needed expenditures for truly satisfactory mosquito control, both under present conditions and up to 10 years in the future, for submission to the CMCA and the Bureau of Vector Control for their use in analyzing future subvention needs.

(3) Questionnaire on types and amounts of spray hoses used by various mosquito abatement districts, especially to obtain information of possible assistance to the Kern MAD, which was having considerable difficulty with its spray hose.

W. D. Murray, *Chairman*
Jack H. Kimball
Thomas D. Mulhern

REPORT OF WILLIAM B. HERMS AWARD COMMITTEE, 1954

In accordance with the action taken at the Twenty Second Annual Meeting of this Association, Forty Dollars ($40.00) was paid to the Mt. Diablo Council, Boy Scouts of America, in memory of Professor William B. Herms, to assist needy Boy Scouts to attend summer camps.

With this money, Scout Harry Shore of Troop 8 was helped to attend Camp Wolfboro for five weeks.

The Scout Executive, Mr. Victor Lindblad, requests that we extend to this Association the thanks of the Mt. Diablo Council, Boy Scouts of America.

The Committee recommends that a further sum of $40 be granted to the Mt. Diablo Council, Boy Scouts of America, for 1955.

The Chairman of this Committee hereby tenders his resignation, as he will not be a resident of the Mt. Diablo Council Area after March 31, 1955.

Very truly yours,
Richard F. Peters
Harold F. Gray, *Chairman*

REPORT OF PUBLICATIONS COMMITTEE, 1954

The "Proceedings and Papers of the Twenty Second Annual Conference of the California Mosquito Control Association," which meeting was held at Berkeley and Oakland, California, December 2, 3, and 4, 1953, were duly published in printed form on May 26, 1954 and delivered to the Secretary-Treasurer for distribution. The Proceedings covered 112 printed pages, a somewhat larger issue than usual. Eight hundred and fifty copies were printed at a cost of $1,487.50.

These Proceedings now have a world-wide distribution, and are in demand because of the quality of the scientific and practical work reported therein. They contribute greatly to the prestige of this Association.

The editorial problem in producing the Proceedings was improved this year by requiring authors of papers to present them in triplicate, and by improving transcription of the recording tapes. A further improvement of these transcriptions will be to have them typed triple-spaced as to lines, for greater convenience of editorial corrections as to grammar, etc., and typed in triplicate copies.

Since this is the last time that the present Editor will report for the Publications Committee, owning to his retirement from active service, he wishes to express his appreciation to the many members of the Publications Committee who have assisted him in the past, and especially to the Secretary-Treasurer and his assistants who have transcribed the tape recordings. His secretary, Margaret A. Prefontaine, has over the past twenty-four years been of the greatest assistance in preparing the manuscripts for the printers.

Bound volumes of the several conference reports from 1930 to 1950, both inclusive, are in the possession of the Alameda County Mosquito Abatement District. There are four volumes, 1930-36, 1937-41, 1944-46, and 1948-50.

It is recommended that the Association bind for record the Proceedings of the 19th, 20th, 21st, 22nd, and 23rd Conferences, (1951-55), and thereafter bind them in five-year groups.

Upon the presentation of this report, the Editor hereby tenders his resignation as Editor of the Proceedings, and extends his best wishes to his successor.

Respectfully submitted,
HAROLD F. GRAY, *Chairman*
JOHN R. WALKER
G. EDWIN WASHBURN

REPORT OF THE WATER RESOURCES COMMITTEE, CMCA

The Water Resources Committee lost two of its principal members early in the year when Chairman Lloyd E. Myers, Jr. left California to join the U. S. Agricultural Research Service staff, and William E. Warner left to take a vector control position in Florida. Thereafter, the committee was dormant until January 3, when President C. Donald Grant requested that I review with the remaining members of the committee the activities which had taken place, and compile a report.

A meeting was arranged on January 4 at the office of the Kern Mosquito Abatement District, and was attended by Richard DeWitt, John Stivers who had been asked to attends because of his familiarity with and interest in the plans which Mr. Myers had been unable to carry out, and the writer. Howard Greenfield was unable to attend because of illness.

A positive accomplishment which can be reported is the completion, by the original committee chairman, of the "Glossary of Terms Used in Irrigation Practice." A copy of the manuscript is submitted herewith, with the recommendation that it be published by the Association, under the authorship of Lloyd E. Myers, Jr., Irrigation Engineer, and Chairman of the 1954-55 Water Resources Committee, CMCA, with additional titles shown to represent his connection with two Federal agencies.

A second positive accomplishment was the securing of copies of the processed material entitled "General Comparison of California Water District Acts," and the distribution of these to all mosquito abatement agencies in the State. This publication outlines the responsibilities and authorities granted the water agencies by the legislature, thereby indicating the areas of concern wherein they may be able to cooperate effectively with mosquito abatement agencies.

Meanwhile, Chairman of the Committee, Mr. Myers, has negotiated an arrangement for the publication of an article in the U. S. Soil Conservation Service magazine, which will present the ways in which that agency may aid in mosquito control. This article now is in the course of preparation and should appear in due course of time.

A beginning has been made on the collection of copies of the printed rules and regulations adopted by various irrigation districts. It is recommended that the incoming committee seek the aid of the various local mosquito abatement agencies in completing this collection, insofar as may be possible, and that subsequently there be compiled and distributed a summary of the data contained therein.

With respect to the "List of Agencies Cooperating in Mosquito Abatement" issued November 10, 1954, by a former committee, it is recommended that the committee determine and record the responsibilities and/or interests of these agencies in the development, storage, transportation, and use of irrigation water, subsequently summarizing and distributing the data to all concerned.

The Committee further recommends for the consideration of the incoming committee the following:

1. That meetings be scheduled at least once every three months, at which time the committee could review with representatives of the Bureau of Vector Control information being received currently by that agency, including such items as the U. S. Bureau of Reclamation "Monthly Progress Report of Project Planing Activities" and "Advance Construction Bulletin," and the California State Department of Public Works monthly listings of "Applications Filed for Permits to Appropriate Water." These documents and other information available could be interpreted and appropriate notice of important developments circulated to the various mosquito control agencies likely to be affected thereby.

2. That the Committee attempt to follow the proposal to form a new "State Department of Water," designed to correlate all water interests, and to study the potential effect of such action upon the mosquito abatement agencies and their respective programs of mosquito control.

3. That there be reviewed the status of water development projects listed in the document entitled "California Central Valley Basin Water Resources Developments—Project Status, May 1952," and that there be prepared an up-to-date report which will advise all mosquito abatement agencies of the present status of these projects.

4. That the present proposals for the development, known commonly as the "Feather River Project," be studied to determine insofar as possible, the areas and mosquito control agencies which will be affected by this development, and the manner in which the effects may be expected to occur.

Respectfully submitted,
THOMAS D. MULHERN,
Interim Chairman
RICHARD DEWITT
JOHN STIVERS
HOWARD GREENFIELD
LLOYD E. MYERS, JR.,
Ex-Chairman

GLOSSARY OF TERMS USED IN IRRIGATION PRATICE[1]

LLOYD E. MYERS, JR.
Irrigation Engineer

INTRODUCTION

Irrigation has been practiced by mankind for over 5,000 years. In the course of that time the people practicing and studying irrigation have developed specialized terms

[1]From the Soil and Water Conservation Research Branch, Agricultural Research Service, Department of Agriculture, and the Communicable Disease Center, Public Health Service, Department of Health, Education and Welfare.

to describe particular structures, practices and phenomena. These specialized terms are not self-explanatory and make the reading of irrigation literature difficult for interested persons who are not familiar with the terms.

Recent emphasis on the relationship of irrigation to public health has made it necessary for many public health personnel to familiarize themselves with irrigation practices and problems, largely through studying the literature. It was primarily to assist these people in reading and understanding irrigation literature that the following glossary was developed.

Readers of this glossary should remember that some of the subjects covered are highly technical and complete explanations including all ramifications involved are beyond the scope of this publication. It is believed, however, that sufficient detail has been set down to convey a reasonable understanding of the terms.

ACRE FOOT: Quantity of water that would cover 1 acre 1 foot deep. An acre-foot is a volume measurement and is equivalent to 43,560 cubic feet.

ACRE-INCH: Quantity of water that would cover 1 acre 1 inch deep; equivalent to 3,630 cubic feet.

ADOBE: A term which originally referred to sun-dried bricks made from fine sandy loam to clay loam soils. More recently the term has been used to describe a structural condition of soils, usually of high clay content, which crack into roughly cubical blocks when dried. The term is loosely, and often incorrectly, used to describe any clay soil.

ABSORB: To hold by absorption. Absorption is the adherence of molecules or ions of dissolved substances, or of fluids, to the surface of a solid body or particle.

ALKALI SOIL: A soil that contains sufficient exchangeable sodium to interfere with water penetration and crop growth, either with or without appreciable quantities of soluble salts. See Saline-Alkali and Nonsaline Alkali Soil.

ANION: Many inorganic compounds dissociate in water into positive elements, or groups of elements, and an equal number of negative elements, or groups of elements. These elements carry units of positive or of negative electricity and are called ions. The positive elements are called cations and the negative elements are called anions. For example, calcium sulfate ($CaSO_4$) in water dissociates into calcium cations ($Ca++$) and sulfate anions (SO_4--).
p. 66.

AQUIFER: An underground formation or structure, through which water can move with comparative ease.

ARID CLIMATE: A climate that is characterized by low rainfall and high rate of evaporation. A region is usually considered as arid where less than 10 inches of precipitation occurs per year.

BASIN IRRIGATION: The application of water to the soil in basins, formed by ridges of soil, which confine the water to the area it is designed to moisten. Commonly used in orchards to irrigate trees. See sketch p. 66.

BERM: (1) The space left between the upper edge of a cut and the toe of an embankment. (2) A horizontal strip or shelf built into an embankment to break the continuity of an otherwise long slope. See sketch below.

BLACK ALKALI: See Alkali Soil and Nonsaline-Alkali Soil. Soils having the undesirable properties of an alkali soil may or may not have a black color, depending upon the quantity of organic matter that is present.

BORDER: An earth ridge built to guide water down a slope or to hold irrigation water within prescribed limits in a field; a small levee.

BORDER DITCH: A ditch on the edge or border of a plot or check to be irrigated. Sometimes used in a combination of field ditch and border strip irrigation where the field ditches form the borders of the border strips. See sketch p. 66.

BORDER STRIP IRRIGATION: The application of water to strips of land bordered by levees which are usually 12 to 100 feet apart. The soil should be level across the strips between levees, with a gentle slope down the length of the strip so that the water can move down the strip in a uniform strip. See "Strip Check" in sketch p. 66.

BOUND WATER: See Hygroscopic Moisture.

CALICHE: A hardpan type of soil cemented with calcium carbonate, or of mixed calcium and magnesium carbonates, characteristic of soils of warm or hot desert and semi-arid regions.

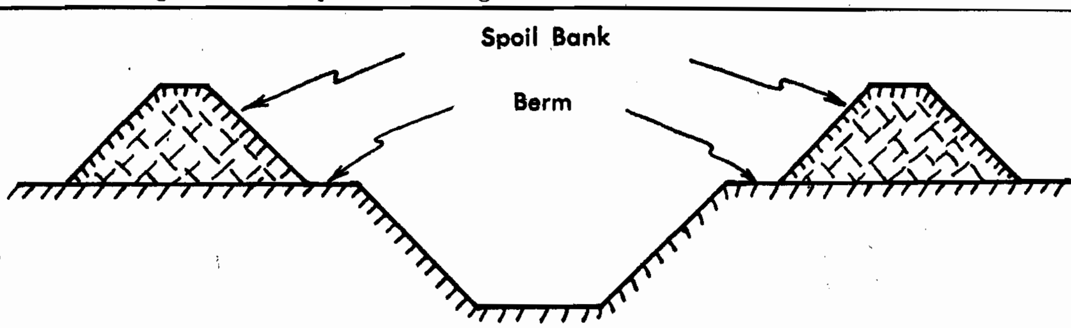
CANAL: An open channel for the conveyance of water, distinguished from a ditch or lateral by its larger size; usually excavated in natural ground.

CAPILLARY WATER: Water held above the water table in soil by capillary force.

CATION: See Anion.

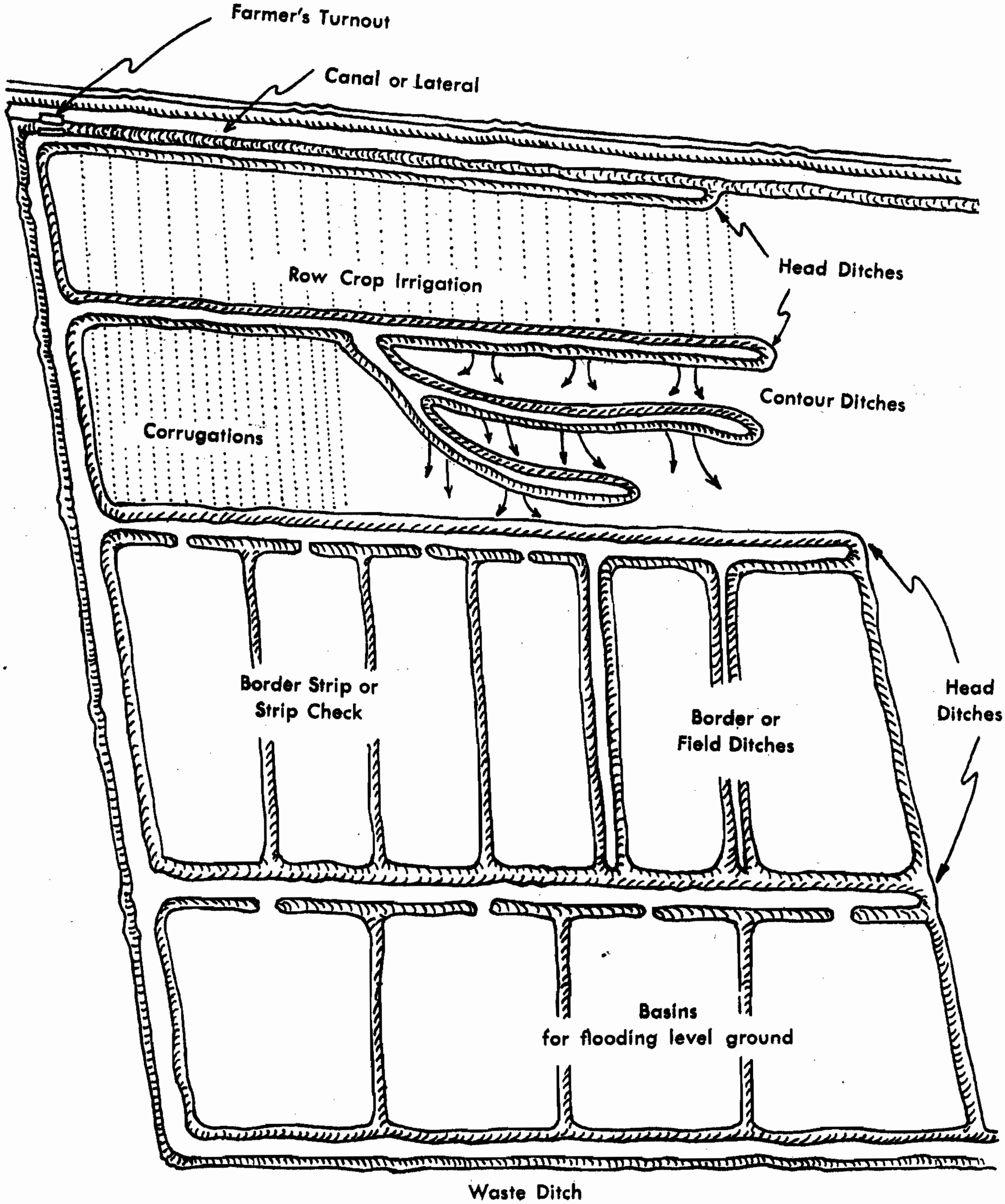
CHECK: (1) A structure designed to raise or control the water surface in a canal or ditch. (2) In irrigation terminology, an area of land enclosed or bordered by levees to control the irrigation water.

CHECK IRRIGATION: A modification of the border-strip method of irrigation in which small earth ridges or checks are constructed at intervals across a border strip to pond water on the soil surface behind each check as the water flows down the strip.



Cross-section of canal showing berms and spoil-banks

IRRIGATION METHODS



CLAY: Soil particles less than 0.002 mm in diameter (USDA classification).

CLAYPAN: A subsoil layer of high clay content, hard when dry and plastic when wet. Water movement and root growth are generally impaired by such a layer.

COLLOIDS: Extremely fine particles of a material. Clay colloids have great influence on the chemical and physical properties of soil. They carry a negative charge and are capable of attracting cations. The laboratory for chemical and physical investigations of soils, U.S.D.A., defines clay colloids as those clay particles smaller than 0.001 mm. in diameter.

CONDUIT: A general term for any channel intended for the conveyance of water, whether open or closed.

CONSUMPTIVE USE: The quantity of water transpired by plants plus that evaporated from the soil surface, or snow, in a given area in a given time. Does not include deep percolation losses or surface run-off losses.

CONTINUOUS FLOW IRRIGATION: A system by which each irrigator receives his alloted quantity of water at a continuous rate. Usually inefficient on small farms where the flow of water is small.

CONTOUR CHECKS: Areas of a field separated by borders which follow the contours.

CONVEYANCE LOSS: Loss of water from a channel or pipe which occurs during the passage of water from the supply source to the point of use. Conveyance losses include losses due to seepage, evaporation and transpiration by plants growing in or near a canal.

CORRUGATIONS: Small ditches, usually closely spaced, used to irrigate close-growing crops such as grain, alfalfa, and pasture.

CUBIC FEET PER SECOND: Sometimes called "second-foot." Commonly abbreviated "cfs." The number of cubic feet of water passing each second a given location in a conduit or structure. One cfs. equals 448.8 gallons per minute (gpm). One cfs. flowing for 1 hour equals approximately 1 acre-inch. One cfs. flowing for 1 day equals approximately 2 acre-feet.

DAYLIGHT: A term used to indicate the process of constructing a ditch with less slope that the slope of the ground surface so that at the lower end the bottom of the ditch "daylights," or coincides with the ground surface, so that water flowing in the ditch can flow out over the surface of the ground.

DEEP PERCOLATION LOSS: Excess irrigation water which percolates to a depth below the root zone and cannot be used by the plants.

DELIVERY BOX: A structure for the control of water delivered to a farm unit. Measuring devices are often included.

DEMAND SYSTEM OF IRRIGATION: A system of irrigation whereby each farmer can obtain irrigation water in the amount and at the time he requests or "demands" it. Most irrigation districts are permitted 24 to 48 hours leeway in the time that the water is delivered. This system permits higher farmstead irrigation efficiency than "rotation" or "continuous flow" systems, but requires larger supply canals and better organization on the part of the supplying agency than do the latter two systems. Good administration of the demand system is very difficult unless storage capacity is available close to the area of water use. Otherwise there is too great a time interval between the time the water is released from the reservoir and the time the water reaches the user who has ordered it.

DIKE: An embankment to confine or control water, especially one built along the banks of rivers to prevent overflow of low lands; a levee.

DISTRIBUTION SYSTEM: (1) The system of ditches, and their appurtenances, which conveys irrigation water from the main canal to the farm units. (2) Any system which distributes water to users.

DITCH: An artificial channel, usually distinguished from a canal by its smaller size.

DIVERSION DAM: A barrier built in a stream for the purpose of diverting part or all of the water from the stream into a different channel or canal.

DIVISION BOX: A structure built into a canal or stream for dividing the water into predetermined parts and diverting it into other canals or ditches.

DRAIN: A channel or pipe line for carrying off surplus ground or surface water.

DRAIN TILE: Pipe made of burned clay, concrete, etc., usually in short lengths, used for constructing drains. See Tile Drain.

DRAINAGE: (1) The process of removing surplus ground or surface water by artificial means. (2) The manner in which the waters of an area are removed.

DRAINAGE BASIN: The area from which water is carried off by a drainage system; a watershed or catchment area.

DROP STRUCTURE: A structure for dropping the water in a channel to a lower level and dissipating its surplus energy. A drop may be vertical or inclined; the latter is called a "chute."

DUTY OF WATER: See Irrigation Requirement.

EFFICIENCY OF IRRIGATION: The fraction of water furnished for irrigation that is "consumed" by the crop, expressed as percent. See Consumptive Use. Can be applied to individual fields, individual farms, or to entire irrigation systems. The efficiency of an irrigation system takes account of conveyance losses.

EQUIVALENT WEIGHT: The weight in grams of an ion or compound that combines with or replaces one gram of hydrogen. The atomic or formula weight divided by its valence.

EXCHANGE COMPLEX: The surface-active constituents of soils (both organic and inorganic) which are capable of cation exchange.

EXCHANGEABLE CATION: A cation that is absorbed on the exchange complex and is capable of exchange with other cations.

EXCHANGEABLE SODIUM PERCENTAGE: The degree of saturation of the soil exchange complex with sodium, expressed as percent. The exchangeable sodium (in milli-equivalents per 100 grams of soil) divided by the total cation exchange capacity (in milliequivalents per 100 grams of soil) multiplied by 100.

FARM DUTY: The seasonal quantity of water delivered to a farm unit.

FIELD CAPACITY: The amount of water retained in a well-drained soil against the forces of gravity at any specific time (usually about 2 to 3 days) after thorough wetting.

FIELD DITCH: A ditch constructed within the field to be irrigated, usually on a contour or slight grade. See sketch p. 66.

FLASHBOARD: A plank, or slab, generally held horizontally in vertical slots on the crest of a dam or check structure, or in a spillway, to control the upstream water level.

FLOW: The movement of water; commonly used to mean the quantity of water moving through a channel or structure in a given period of time; sometimes used to mean the rate of flow.

FLUME: An open conduit of wood, concrete, metal, etc., usually supported on a prepared earth grade, trestle or bridge. A large flume is also termed an aqueduct.

FREEBOARD: The distance left between the normal operating water surface and the top of the sides in an open channel, the crest of a dam, etc., to prevent the water overtopping the structure as a result of wave action, floating debris, or any condition or emergency.

FURROW: A small ditch constructed to guide the flow of water across the land being irrigated. The water soaks into the soil from the furrow. Used to irrigate row crops.

GATED PIPE: Portable pipe constructed with a number of small gates along one side so that water may be run from the pipe into corrugations or furrows.

GRAVITY WATER: (1) Water that moves through the soil under the influence of gravity. (2) A supply of water which flows into the distribution system under the force of gravity, as distinguished from a pumped supply.

GROUND WATER: Water in soil below the ground surface, usually under conditions where the pressure in the water is greater than atmospheric pressure, and the soil voids are substantially filled with the water.

HARDPAN: Hardened or cemented soil horizon. Claypan may or may not be hardpan.

HEAD: (1) The height of water above any point or plane of reference. (2) Sum of the energy which a body of water possesses by virtue of its velocity, pressure and position, expressed as height to which the water would rise above a given datum if all the energy were converted to potential (position) energy. (3) Rate of flow used in irrigation. See Irrigating Head.

HEAD DITCH: Ditch run across upper side of field used for distributing water to furrows or checks.

HEAD GATE: Gate structure at upper end of a ditch to control the flow of water into the ditch.

HORIZON: In soil terminology, a layer of soil which differs from the material (soil, rock, water or air) above and below it.

HYGROSCOPIC MOISTURE or WATER: Soil moisture, absorbed by soil particles, that can be driven out of the soil only by heat. Not available to plants.

INFILTRATION: The process of water soaking or moving into the soil through the soil surface. Not the same as percolation.

INVERT: The floor, bottom, or lowest part of the internal cross-section of a lined channel or pipe.

INVERTED SIPHON: A pipe line crossing over a depression or under a canal, road, etc. The term is common but not correct, since no siphoning action occurs.

IRRIGABLE AREA: The area under an irrigation system capable of being irrigated, principally as regards quality and location of land. It may include roads, farm lots, building sites, and miscellaneous areas not actually irrigated.

IRRIGATING HEAD: (1) The flow (quantity of water flowing per unit of time) used for irrigation of a particular tract of land. (2) The flow of water distributed at a single irrigation, or the flow in a single farm lateral. (3) The flow rotated among a group of irrigators.

IRRIGATION: Artificial application of water to soil for the purpose of supplying moisture essential to plant growth.

IRRIGATION REQUIREMENT: The relation between the area of land served and the quantity of irrigation water used per unit of time. It may be expressed as the area irrigated with a given flow for a given period of time, rate of flow per acre for a particular time, or the amount of water applied in acre-feet or acre-inches per acre each year. It is a measure of the use of water and may be distinguished as head gate or gross duty, lateral duty, farm duty, net duty, or crop duty for different crops.

LATERAL: (1) A channel or pipeline diverting water from a main channel or pipeline for delivery to farm ditches. (2) A secondary ditch.

LEACHING: The process of removing soluble material from soil by the passage of water through the soil.

LENGTH OF RUN: (1) The distance water must run in furrows or over the surface of a field from one head ditch to another, or to the end of the field. (2) The period of time that one irrigator is allowed the irrigating head, in the system of rotation deliveries.

LEVEE: An embankment of earth constructed to divert or confine the flow of water. Usually applied to large embankments, but may be used to describe small ridges or borders.

LOAM: Soil material containing 7-27 percent clay, 28-50 percent silt, and less than 52 percent sand.

MAIN CANAL: The main canal which conveys water supply from the source to the irrigated area.

MILLIEQUIVALENT: Equivalent weight/1000.

MINER'S INCH: A rate of flow. The discharge from an orifice 1 inch square under a definite head. The value of a miner's inch has been fixed by statute or practice in various states but varies among different states. In Colorado, 38.4 miner's inches equal 1 cfs. In Arizona, northern California, Montana, Nevada and Oregon, 40 miner's inches equal 1 cfs. In southern California, Idaho, Kansas, New Mexico, North Dakota, South Dakota, Nebraska, and Utah, 50 miner's inches equal 1 cfs.

MOISTURE EQUIVALENT: An arbitrary moisture value used as an estimate for the field capacity of soils. It is the weight of water remaining in a soil sample (expressed as percentage of the dry weight of soil) after the soil has been saturated and subjected for 30 minutes to a centrifugal force 1,000 times gravity.

NONSALINE-ALKALI SOIL: A soil which does not contain appreciable quantities of soluble salts, but which contains sufficient exchangeable sodium to interfere with water penetration and the growth of most crop plants.

OUTFALL: The point where water flows from a channel or pipeline; the mouth of drains and sewers.

PERCOLATION: Movement of water through small passages in a body of material, as through the pores and cavities of soil.

PERMANENT WILTING PERCENTAGE: The moisture content below which plants cannot readily obtain water. It is the soil-moisture condition at which plants wilt and do not recover unless water is applied to the soil. Generally expressed as the percentage of soil moisture based on the dry weight of the soil.

PERMEABILITY: The specific property of a porus medium (such as soil) which is a measure of the readiness with which the medium transmits fluid under standard conditions. Permeability is usually expressed as a velocity and for agricultural purposes can be conveniently expressed in inches per hour.

PLOWSOLE: A zone of compacted soil, beginning at the depth of cultivation, created by cultivation tools or passage of heavy equipment. Commonly created through compaction by sole of plow acting at the same depth for a period of years.

POROSITY: The fraction of the soil volume not occupied by soil particles; the ratio of the volume of pores to the total volume of the soil.

PRECIPITATION: Rainfall and snowfall, usually expressed as inches of water.

REACH: A comparatively short length of a stream or channel.

RETURN FLOW: That portion of the water diverted from a stream for irrigation which finds its way back to the stream channel, either as surface or underground flow.

RIPARIAN: Pertaining to the banks of a body of water; a riparian owner is one who owns the banks; a riparian water right is the right to use and control water by virtue of ownership of the bank or banks.

ROOT ZONE: That part of the soil invaded by plant roots.

ROTATION IRRIGATION SYSTEM: A system of irrigation through which a number of irrigators rotate the use of the water ,each taking all or a portion of the entire flow in turn for a limited period of time. Under some of the larger canals the total flow is divided into "heads" which are rotated among the users.

RUNOFF: (1) The portion of precipitation which appears as flow in streams. It may reach the stream through surface flow or through groundwater flow. (2) The portion of applied irrigation water which does not soak into the soil and runs off as waste water.

SALINE SOIL: A nonalkali soil containing soluble salts in such quantities that they interfere with the growth of most crop plants.

SALINE-ALKALI SOIL: A soil containing sufficient exchangeable sodium to interfere with the growth of most crop plants and containing appreciable quantities of soluble salts.

SAND: Soil particles ranging from 0.05 to 2.0 mm in diameter (USDA classification).

SECOND-FOOT: One cubic foot per second.

SEEPAGE: The slow movement of water into, through, or from soil. Seepage into a body is referred to as influent seepage; that away from a body as effluent seepage.

SEMI-ARID: A term applied to a country or climate with precipitation ranging from about 10 to 20 inches per year.

SILT: Soil particles ranging from 0.002 to 0.05 mm in diameter (USDA classification).

SIPHON: A tube or pipe, usually bent in the shape of an inverted "U" by which water can be transferred from an upper level, over an obstruction, to a lower level. Atmospheric pressure forces the water up the shorter, or upper, leg of the siphon while the excess weight of the water in the longer, or lower, leg causes flow. Small siphons are commonly used to divert water from ditches to furrows or checks. Their use eliminates the need for cutting the ditch banks, which is often a distinct advantage.

SLICK SPOTS: Small areas in a field that are somewhat slick when wet, usually due to alkali or high exchangeable sodium.

SODIUM PERCENTAGE: The percentage of total cations in water, or the soil solution, that is sodium. Calculations are usually on an equivalent rather than weight basis.

SOIL: Finely divided material composed of disintegrated rock mixed with organic matter; the loose surface material in which plants grow.

SOIL PROFILE: A vertical cross-section of the soil horizons.

SOIL STRUCTURE: Soil structure is determined by the arrangement and coherence of the soil particles; i.e., dispersed, granular, cloddy, cracked into prismatic columns, etc.

SOIL TEXTURE: Soil texture is determined by the proportions and gradations of the three sizes of soil grains, i.e., sand, silt and clap, present in the soil.

SPECIFIC YIELD: The ratio of volume, or weight, of water a soil will yield to the force of gravity, after being saturated, to its own volume, or weight.

SPILE: A tube, made of lath, pipe, or rubber hose, placed in ditch banks to transfer water through the banks from the ditch to the field.

SPOIL BANK: During the construction of a ditch or canal, the excavated material, or "spoil" is usually piled on one or both sides of the excavation. The resulting embankments are called "spoil banks." See sketch under Berm.

SPRINKLER IRRIGATION: A method of irrigation, in which the water is sprayed, or sprinkled, over the surface of the ground. Ideally, the water is applied at the rate at which it will soak into the soil so that no standing water remains. This method is particularly advantageous on uneven ground where leveling is impossible or very expensive, or on sandy soils where other irrigation methods result in excessive deep percolation losses.

STAFF GAGE: A linear scale located on a staff, plank, pier wall ,etc., extending into the water, by which the elevation of the water surface may be read.

STAND PIPE: A vertical, open-ended pipe or tank connected to a pipeline to release air from the system and to prevent the development of excessive pressure by surges within the system.

STRIP CHECK: See Border Strip.

STRUCTURE: See Soil Structure.

SUBIRRIGATION: (1) Watering plants by applying the water below the ground surface. (2) Irrigation by raising and lowering the water table within or near the root zone, often under control.

SUBSOIL: The material lying below the surface soil, generally devoid of humus or organic matter.

SUBSOILING: Tillage operations primarily concerned with breaking up the soil below plow depth.

TAIL WATER: (1) The water, in a river or channel, immediately downstream from a structure. (2) The excess irrigation water which reaches the lower end of a field.

TEXTURE: See Soil Texture.

TILE DRAIN: A drain constructed by laying drain tile, with unsealed joints, in the bottom of a trench which is re-filled after the tile is laid. Tile drains are installed to remove excess water from the soil.

TURNOUT: A structure used to divert water from a canal to a farmer's lateral.

UNIT HEAD: The amount of water turned into each furrow or border check during irrigation.

WASTEWAY: A channel which conveys or discharges excess or waste water from a canal or river.

WATER APPLICATION EFFICIENCY: The fraction of the water delivered to the farm that is stored in the root zone for use by the crop, expressed as percent.

WATER RIGHT: A legal right to the use of water.

WATER SPREADING: The artificial application of water to lands for the purpose of recharging groundwaters for subsequent withdrawal.

WATER TABLE: The elevation at which pressure in unconfined ground water equals atmospheric pressure; the elevation at which water stands in a hole dug down to the water table.

WATERLOGGED: A condition of lands where the water table stands at a high level that is detrimental to plants. It may result from over-irrigation or seepage with inadequate drainage.

WEIR: (1) A dam across a stream for diverting the flow into a canal. (2) a device for measuring the flow of water.

WHITE ALKALI: See Saline Soils.

WILD FLOODING: Relatively uncontrolled flooding of fields which have not been prepared for uniform irrigation.

WILTING COEFFICIENT or PERCENTAGE: See Permanent Wilting Percentage.

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Seelye, Elwyn E.: Data Book for Engineers, Specifications and Costs; John Wiley & Sons, New York, N. Y.; 1946.

REPORT OF OPERATIONAL INVESTIGATIONS COMMITTEE

Throughout the year projects supported by California Mosquito Control Association progressed in good order. Committee meetings were held in the early months of the year to establish policy, budget, and procedures. As a pattern was developed, project personnel took over in such good fashion that further committee meetings seemed unnecessary. Projects undertaken and a summary of accomplishments were:

I. IRRIGATED PASTURE STUDIES.

A. Influence of post-ovipositional condition on the hatching of *Aedes nigromaculis* eggs.
A study undertaken to reveal the factors that control or influence egg hatching. Observations have indicated that the chemical or physical properties of the egg shell contribute to the hatchability of an egg. (Miss Rosay)

B. Distribution and abundance of *Aedes* eggs in an irrigated pasture.
Data obtained were not significant because of limitations imposed by experimental circumstances and time. (Mr. Husbands)

C. Study of the evolution of an uncontrolled irrigated pasture.
A continuing study—initiated in 1951 in Madera County in a selected study pasture — to evaluate field conditions and their influence upon mosquito populations and pasture deterioration.
Results indicate that deterioration is a continuing process with great influence upon mosquito species. (Mr. Husbands)

II. COOPERATIVE PASTURE STUDY.

A. The determination of the relationship between irrigation practices and mosquito production.
A joint irrigation-mosquito study with the Agricultural Research Service, USDA, to evaluate present irrigation practices and establish the relationship between irrigation efficiency and mosquito production. To provide also information on the relationship between crop production, mosquito production, and irrigation efficiency. (Mr. Husbands and Mr. Davis)

III. RICE FIELD STUDIES.

A. Algal transplant studies.
Five fields were inoculated with rice stubble carrying cysts of *Anabaena*. Of the five plots, four showed good growth of the blue-green algæ. A corresponding reduction of mosquitoes was noted. (Mr. Gerhardt)

B. Field survey of blue-green algæ in rice fields.
A continuing study designed to secure information concerning the distribution and effects of the algæ in California rice fields. (Mr. Gerhardt)

C. Insecticide-predator relationship study.
To determine the effect of an insecticidal application on the predators in rice fields. (Mr. Gerhardt)
On the basis of data available it seems that a single larvicidal application may do more damage than good by reducing natural predators of mosquito larvæ. (Mr. Gerhardt)

D. Limnological Studies.
This season's work on limnology was restricted to some aspects of quantitative plankton measurements. It was designed to test the techniques used as regards their applicability to the research problems being considered by the project. (Mr. Gerhardt)

IV. JOINT STUDY ON THE MODE OF ACTION OF BLUE-GREEN ALGÆ ON MOSQUITO LARVÆ.

This work is largely in support of activities of the Department of Plant Nutrition, University of California, Berkeley. (Mr. Gerhardt, Dr. Arnon, Dr. Allen)

V. CULTURAL ASPECTS OF RICE FIELD MOSQUITO ECOLOGY STUDY (Mr. Stone)

A. Rice water flows: circulated water vs. non-circulated water.
B. Intermittent submergence of rice paddies.
C. Depth of water in rice field warming basins at Biggs and Wylie Stations.
D. Influence of fertilizers on mosquito production.
E. Effect of rice field weed herbicides on mosquito production.

The committee commends the excellent work accomplished by all project personnel. Full credit for the fine administration of the projects must be given to Dr. Basil Markos. His guidance, plus the many other contributions by the Bureau of Vector Control, made it possible to expand the investigations far beyond the resources of California Mosquito Control Association.

Respectfully submitted,
T. G. Raley, *Chairman*
Edward E. Davis
Thomas M. Sperbeck
Lewis W. Isaak
Basil G. Markos
Lloyd E. Myers

REPORT OF THE CULICIDOLOGY COMMITTEE

The California Mosquito Control Association Culicidology Committee has continued its assignment of exploring ways and means which would lead to a generally acceptable recommendation for evaluating mosquito population densities. Many methods and techniques have been used by California agencies in recent years, but gross inadequacies still exist. The last guide to the evaluation of mosquito population density presented by this Committee was included in the Proceedings of the 22nd Annual Conference.

This past season the Culicidology Committee conducted a survey among mosquito abatement agencies, having the following objectives:

1. Summarize evaluation methods used in 1954.
2. Compare the economics of methods used.
3. Recommend a continuing density evaluation program based on survey data.

Due to the detailed nature of the survey requirements, the Committee decided that information could be best acquired through personal interview with District personnel. Each agency received the Mosquito Measurement Program survey form, a copy of which is attached hereto. One Committee member was assigned to each of the regional areas of the State for data gathering. The personal contact, even though considerably more time-consuming allowed us to gain a more comprehensive concept of the needs than would otherwise have been obtained through mail correspondence alone.

The analysis of the data obtained has required a large amount of time, and as of now, information is not yet in from nine agencies; consequently the Committee will need additional time to complete its survey. It will be our intent to present the objectives of the survey at the first California Mosquito Control Association Board of Directors meeting following the present Conference.

The Culicidology Committee submitted at the 21st Annual Conference of the California Mosquito Control Association a list of culicidology projects currently under investigation and future project projosals. A recently compiled list of said projects is attached to this report. Compilation of this information is a continuing function of the Committee.

The Committee wishes the Association to consider the proposal of undertaking, as an Association project, the compilation of California Culicidology data. Such a project would emphasize ecology distribution, taxonomy, and public health aspects, and would exclude control measures. The Culicidology Committee could logically guide this project, and an indefinite number of contributors could be involved in the assemblage of data. Due to the expansion in our knowledge of mosquito biology, the project might prudently be allowed to go through two revisions before being considered for publication.

Supplement to "Mosquitoes of California" By Freeborn and Bohart

During the past season, R. Bohart and E. C. Loomis completed a mosquito distribution supplement based on identified California specimens. This data has been assembled as a supplement and will be made available with reprinted copies of Freeborn & Bohart, 1951 "Mosquitoes of California."

Recommendations

Inasmuch as the mosquito control agencies have felt that the measurement survey was important, the Committee should continue its statistical analysis of the program and report same with proposals for improvements. A plan leading to the publication of a comprehensive work on the mosquitoes of California (a cooperative Association project), emphasizing ecology, should be investigated. The Committee should continued to make available lists of culicidology projects, current and anticipated, in California and should be available to generally serve at the pleasure of the Association.

Respectfully submitted,
Theodore Aarons, *Chairman*
Richard C. Husbands
Edmond C. Loomis
Embree G. Mezger
John C. Shanafelt, Jr.

LIST OF CURRENT AND PROPOSED INVESTIGATIONS (RESEARCH) IN CALIFORNIA

Note: This list has been compiled and based primarily upon a survey of all persons and agencies interested in mosquito problems in California. The first part of the list shows work presently active or in progress during 1954. The second part of the list is a compilation of proposed programs or investigations (research) subjects that may be conducted in the near future. The third part deals with investigation subjects that have been proposed but for which there is no immediate program contemplated.

I. Current Projects

A. C.M.C.A.-B.V.C.
   1. Irrigated Pasture Mosquito Ecology Study.
   2. Ricefield Mosquito Ecology Study.
   3. Tests on the Performance of Adulticiding Machines.

B. U.S.D.A., Ento. Res. Br.
   1. Field Tests of Malathion and Chlorthion Aerosols.

C. U.S.D.A., Ento. Res. Br.
   1. Laboratory Tests on *Culex quinquefasciatus* using newer organic phosphorus insecticides.

D. Bureau of Vector Control.
   1. Measurement Studies on Mosquito populations within artificial and natural rest stations.
   2. Studies on K.A.A.D. clearing-killing fixative for larvae collected in the field.
   3. Maintenance of a series of adult *C. tarsalis* and *C. stigmatosoma* in a study of their variability in California.

E. University of California, Hooper Foundation, and U. S. Public Health Service.
   1. Cooperative studies on the ecology of the arthropod-borne virus: vector and reservoir.

F. University of California.
   1. Biology of *Aedes dorsalis* and *Aedes squamiger.*
   2. Mosquitoes of Micronesia.

G. Mosquito Abatement Districts and Agencies.
   1. Refinement of measurement techniques (visual) on adult *A. varipalpus.*
   2. Effectiveness of aerosol on *A. varipalpus* adults.
   3. Biology of *C. tarsalis* in salt marshes.
   4. Biology of *A. squamiger.*
   5. Role played by muskrats in damage to flood gates.
   6. Biology and control of treehole mosquitoes.
   7. Use of wetting agents for mosquito control.
   8. Experimental use of Oronite D-40 at sewage disposal plant.
   9. Study of zoo birds to determine percentage of birds infected with avian malaria.
   10. Surface Tension Reduction.
   11. *Aedes varipalpus* control—continuation of observation on efficiency of tree hole filling.
   12. Mist Blower Development.
   13. Emulsifier tests.
   14. Rice field mosquito predator biology.
   15. Screening and evaluation of insecticides for mosquito control.

Location

State of California, Vector Investigations Unit, Fresno Facility, State Department of Public Health, 5545 East Shields Avenue.
University of California at Davis, (Branch Vector Investigations Unit).
Merced Area.
Merced Area.
Corvallis, Oregon.
Bureau of Vector Control, 2180 Milvia Street, Berkeley, California.
Ditto
Ditto
Bakersfield Field Station, P. O. Box 1564.
University of California at Davis, Dr. Bohart.
University of California at Davis, Dr. Bohart.
Marin County MAD.
Ditto
Solano County MAD.
Ditto
Contra Costa MAD.
Butte County MAD.
San Diego County Department of Public Health.
Ditto
Ditto
Northern Salinas Valley MAD.
Alameda County MAD.
Merced County MAD.
Ditto
Ditto
Kern County MAD.

II. Future Projects (Program Contemplated)

A. Bureau of Vector Control.
   1. Irrigated Pasture Project.
   2. Rice Field Project.
   3. Cotton Field Project.
   4. Natural Sources Project.
      Culex tarsalis
   5. Toxicology Project.
   6. Equipment Evaluation.
   7. Mosquito Source Reduction.
   8. Blue-green algæ studies.
   9. *Aedes* Egg Hatching Studies.

B. Mosquito Abatement Districts and/or Agencies.
   1. Effectiveness of Granules on Control of Tree Hole Mosquitoes.
   2. Cooperative Study with Bay Area MADs on *Culex* Resistance to Chemical Control.
   3. Effectiveness of Oils on Mosquitoes in Sewage Oxidation Ponds.
   4. Study of the Relationship of Predators and Mosquitoes Occurring in Rice Fields.
   5. New Insecticides—Testing for Immature and Adult Mosquito Control.
   6. Study on the Effect of Control of Mosquito Sources Around Rice Fields to the Mosquito Population within Rice Fields.
   7. Biology of *O. californica.*

C. University of California.
   Revision of "Mosquitoes of California" (1951)
   2. Biology of *C. stigmatsoma.*
   3. Taxonomy of 1st Instar *Culex* Larvæ.

Location

Administered by Vector Investigations Unit—BVC, Fresno.
Ditto
Ditto
Ditto
Ditto
Ditto
Ditto
Ditto. N. I. H. Grants.
Administered by Vector Investigations Unit—BVC, Fresno. N. I. H. Grants.
Marin County MAD.
Napa County MAD.
Ditto
Fresno MAD.
Ditto
Sutter-Yuba MAD.
San Mateo MAD.
Davis, California.
Dr. Bohart.
Ditto
Ditto

III. Future Projects Proposed for Investigation.

A. By C. M. Gjullin, U.S.D.A.
   1. Laboratory screening of new insectcides as larvicides and adulticides and field-testing of the more favorable materials.
   2. Testing and improving equipment for the application of these materials.

3. Laboratory and field-screening of chemicals which may attract or repel mosquitoes.
4. Development of better methods of sampling adult mosquito populations.
5. Detailed studies of the biology of mosquitoes in relation to water, soil, and climatic conditions in various parts of California.
6. Studies to determine the factors which cause *Aedes nigromaculis* eggs to hatch.
7. Studies of the physiology of the important species of mosquitoes to discover hormones or enzymes that may be responsible for molting and pupation.
8. Studies to determine migration patterns of important species and conditions which may cause migration.
9. Taxonomic studies to find more reliable characters for separating species which are similar in appearance.
10. Development of rearing methods which will insure availability of large colonies of the California strain of *Culex tarsalis* at all times.
11. Development of educational films to show the most simple and effective methods of source reduction of mosquito breeding in the situations commonly occurring in irrigated areas. Compilation of figures to show the increased crop values that are obtained by this improvement.
12. Studies to indicate the increase in beef and milk production through control of mosquitoes in pastures.
13. Research on diseases affecting the various stages of the mosquito, and methods whereby these may be used as a control measure.

B. Dr. S. B. Freeborn, U. C. Davis.
1. Determine why *A. nigromaculis* replaced *A. dorsalis* in California.
2. Delineation of areas in California where *A. dorsalis* is preferred to *A. nigromaculis.*

C. E. C. Loomis, BVC, Berkeley.
1. Population measurements methods as applied to *Aedes varipalpus.*
2. Light trap evaluation studies on proper light intensity, color, maximum recovery hours, and species selection.

D. R. E. Bellamy, PHS, Bakersfield.
1. Biology of *Culex tarsalis.*

E. C. E. Robinson, East Side MAD, Modesto.
1. Toxicology studies.
2. Flight range studies.
3. Biological control studies.

F. John O. Stivers, Merced MAD.
1. Late summer flight range of *C. tarsalis.*
2. Food preferences of *C. stigmatosoma.*
3. Investigate natural toxicants (e.g. rice algæ) for use on irrigated pastures.
4. Tule and cattail control.

G. J. B. Askew, San Diego, D.P.H.
1. Study of dairy wastes and control of mosquito breeding thereon.

H. H. I. Magy, BVC, Los Angeles.
1. Mosquitoes found in cemeteries—ecology and chemical control.
2. Mosquito problems and control procedures in sewage oxidation ponds.

I. R. C. Husbands, CMCA, Fresno.
1. Statewide distribution of species of mosquitoes associated with irrigated pastures.
2. Studies of adult mosquito habits:
   a. Sex ratio variations.
   b. Mating.
   c. Oviposition habits.
   d. Longevity.
   e. Feeding.
   f. Age, feeding, gravidness, etc. influence upon dispersal or flight.
3. Taxonomic studies to determine potential segregation and sub-species.
4. Review of the literature as a possible means of uncovering species of mosquitoes potentially capable of entering California from other parts of the world.
5. Studies that would demonstrate the influence of of altering known environmental conditions that will lead to mosquito control in irrigated crops.
6. Studies on the statistical problems relating to virus recovery from samples of mosquitoes with a low ratio of positive to negative specimens, such as exists in the *Aedes* species mosquitoes.
7. Host preference studies and the influence of the first blood meal host type upon further feeding preference.
8. Studies upon the transmission of disease to livestock.
9. Studies on the genetics of laboratory strains of mosquitoes.

REPORT OF THE LEGISLATIVE COMMITTEE

At the California State Legislature the State Department of Public Health included $700,000 subvention to assist local agencies. This amount was cut to $400,000 in the Governor's budget as submitted to the Legislature.

The Asembly Ways and Means Committee held a hearing at which time we presented the reasons why the $700,000 subvention was necessary for adequate mosquito control. We were defeated by a vote of 9 to 11 of this committee.

Assemblyman Ernest Geddes presented a motion to amend the budget from $400,000 to $700,000. This won in the Assembly by a vote of 32 to 30.

Neither the Assembly nor the Senate accepted the other budget and a Conference Committee was appointed, composed of three Senators and three Assemblymen, to adjust the differences between the two budgets. The conference Committee approved the $400,000 subvention aid and $150,000 emergency appropriation to be used upon recommendation of the Director of Public Health and approval of the Director of Finance in case of an anticipated encephalitis emergency. The 1954-55 budget, with these items, was approved by the Legislature and signed by the Governor.

The State Department of Public Health, in their budget for 1955-56 included $725,000 for State subvention, plus 10 percent of this amount for studies and investigations. All but the $400,000 subvention was deleted in the Governor's budget. Your Legislative Committee, through Assemblyman Ralph Brown, has presented a bill to replace the $325,000 in the State Department of Public Health's budget. Hearings before the Assembly Ways and Means and Senate Finance Committees regarding this bill probably will be held in March of 1955. This bill can be amended to include other items recommended by the C.M.C.A.

Assemblyman Ralph Brown also is presenting a bill amending 2206 of Health & Safety Code to exempt mosquito abatement districts for another two years from the District Investigation Act of 1933. He is also presenting a bill to form a California Council of Mosquito Abatement Agencies. This bill will not be presented to the Legislature until approved by a majority of the agencies involved.

You will be informed when these bills have a number and it is imperative that you immediately inform your State Legislators of the necessity for their passage.

Respectfully submitted,
E. Chester Robinson, *Chairman*
Harold Gray
Dick Sperbeck
Art Geib

REPORT OF THE AUDITING COMMITTEE

The Auditing Committee has made an examination of the books, and have found that they appear to be in very good order.

We should like to recommend to the Board of Directors of this Association that the audit be made by a certified public accountant because of the time element. The books are closed at the end of the calendar year, with the conference following very soon thereafter. It is difficult for an auditing committee to meet and audit the books in the available time.

Respectfully submitted,
Marvin C. Kramer, *Chairman*
John O. Stivers

REPORT OF THE RESOLUTION COMMITTEE

Three resolutions have been considered by the Committee and are presented at this time for your approval.

RESOLUTION NO. 1

WHEREAS, copies of the minutes of the various meetings of the Board of Directors have been sent to all members of this Association

BE IT RESOLVED, that the actions taken by the Board of Directors during the past Conference year, as reported by these minutes, be approved by the members assembled at this 23rd Annual Conference.

RESOLUTION NO. 2

WHEREAS, A. M. Emerick, a pioneer in California Mosquito Control, a charter member and President of this Association in 1935, and superintendent of the Napa County Mosquito Abatement District from 1928 until his retirement several years ago, passed away in the fall of 1954; and

WHEREAS, Mr. Emerick, affectionately known to his friends as "Ham" Emerick, was a unique individual possessing the unusual ability of being able to be in the right place at the right time to handle individually and personally the mosquito needs of Napa County.

BE IT RESOLVED, by the California Mosquito Control Association, assembled this 25th day of January, 1955 in its 23rd Annual Meeting at Los Angeles, California, that we express our regrets at the death of Mr. Emerick by sending a copy of this Resolution to his widow with our condolences on her loss.

RESOLUTION NO. 3

WHEREAS, the technical presentations and the meeting arrangements for the 23rd Annual Conference of the California Mosquito Control Association held jointly with the American Mosquito Control Association at Los Angeles with headquarters at Hotel Statler and with one day at the campus of the University of California in Westwood, have been particularly outstanding and enjoyable

BE IT RESOLVED, by the members of this Association assembled here at its annual business meeting on January 25, 1955, that we hereby express our appreciation and thanks to all who have participated in the program and in the conference arrangements.

BE IT FURTHER RESOLVED, that the Secretary-Treasurer of this Association is hereby directed to send letters of appreciation and thanks to all those who have so participated or contributed and, in particular, to the following:

The University of California at Los Angeles for making possible "University of California Day," with special thanks to Dr. Walter E. Ebeling, Head of the Department of Entomology; to Dr. Dr. John N. Belkin, as chairman of our Program Committee; to Mr. A. Harry Bliss, School of Public Health, as chairman of our events on the campus; to Dr. Leland R. Brown and Mr. Wm. A. McDonald, Department of Entomology; and to Mr. Sam Houston, Conference and Special Activities, for a very successful field demonstration of equipment in ornamental horticulture area.

The Los Angeles City Health Department for being host to the Joint Conference with special thanks to Dr. George M. Uhl, Health Officer, and Charles L. Senn, Engineer-Director, Division of Sanitation, and to W. E. Duclus, John Ruddock, and Messrs. McKenzie, Moundy, and Badon.

The Los Angeles County Museum, with special thanks to Dr. Fred S. Truxal for coordinating all submitted papers.

The Los Angeles County Health Department, with special thanks to Mr. Stanley Martin, for its cooperation with the Southeast Mosquito Abatement District on the Exhibits and Finance Committee.

The California State Department of Public Health, Bureau of Vector Control, for providing an excellent exhibit, for their many contributions to the program, and for the many other services and assistance with special thanks to Richard F. Peters and Harvey I. Magy.

To Mrs. Walter E. Ebeling and her committee for an outstanding ladies program.

To Neil A. MacLean Company, for the outstanding job performed by its representative, Norman R. Ehmann, during the past six months as chairman of the Joint Conference Committee.

The Los Angeles Chamber of Commerce.

The Management of the Statler Hotel, with special thanks to Mr. Hewitt.

To John G. Shanafelt, for printing the program and the various tickets.

To all the Exhibitors for the informative displays and demonstrations.

To the Orange County Mosquito Abatement District, for mailing some 1500 programs, for furnishing an exhibit booth and display material, and for doing the registration and ticket sales, with special thanks to Jack H. Kimball, John G. Shanafelt, and Albert H. Thompson.

To the Southeast Mosquito Abatement District, for securing and coordinating the many fine commercial exhibits, and for handling the financing of the Conference, with special thanks to Gardner C. McFarland.

Respectfully submitted,
JACK H. KIMBALL, *Chairman*
GARDNER C. MCFARLAND

REPORT OF THE NOMINATING COMMITTEE

The general membership of the California Mosquito Control Association was notified of this Committee's selections by mail on January 13, 1955, as per the following letter:

"According to the By-Laws of this Association, the general membership is to be advised of the proposed officers of this Association for the next ensuing year. The Nominating Committee, therefore, has asked that this office notify you of its selections, who will be voted upon at the coming 23rd Annual Conference. The selectees are as follows:

President . . . . . T. M. (DICK) SPERBECK
Vice-President . . . . . W. DONALD MURRAY
Secretary-Treasurer . . . G. EDWIN WASHBURN
Trustee Member . . . . . ROY L. HOLMES

Respectfully submitted,
Nominating Committee
EDGAR A. SMITH, *Chairman*
L. S. HAILE
JACK H. KIMBALL
ROBERT H. PETERS
CHESTER ROBINSON

President Grant: Gentlemen, you have heard the nominations made by the Nominating Committee. Mr. Washburn, have there been any other nominations submitted in accord with proper procedure?

Mr. Washburn: No, there have not.

President Grant: With the consent of the general membership, I shall ask Mr. Washburn to cast a white ballot for the candidates proposed by the Nominating Committee.

Thank you. May I ask the newly elected Officers to arise and be introduced?

Congratulations, Dick. Thank you for relieving me from my over-extended term of office, and I wish you every success in the problems that you have inherited.

Mr. Sperbeck: If you all feel like I do, we know we have had a long day. There is one thing I want to do as President of this organization, after thanking you all for the honor, is to introduce the President of my Board of Trustees, Mr. Marion Bew from Marysville, who has a message to present to you, and I promise that all messages will be short. Mr. Bew: he is past City Councilman, City of Marysville, Ex-Mayor, President of the Sutter-Yuba Board of Trustees, and most of you know him as the operator of the beautiful motel on the lake in Marysville.

Mr. Bew: I know how to make short speeches but my function here tonight is in a dual capacity of the Board of Trustees of the Sutter-Yuba Mosquito Abatement District and also representing the Yuba-County-Marysville Chamber of Commerce, in extending an invitation to the California Mosquito Control Association to hold your next Annual Conference in Marysville in 1956. Most of you know Marysville, and those of you that don't, should. I'd like to present this little brochure to your Secretary; it contains a letter from our Mayor, Mr. Roy G. Cunningham, and other letters of invitation that you can read at your leisure, and also a brief brochure on what Marysville has to offer. Thank you for your time, and I hope you will give Marysville consideration for your 1956 conference.

Mr. Sperbeck: Thank you, Marion. This will be referred to the Board of Directors at their next meeting to take appropriate action.

The meeting is adjourned.

FIFTH SESSION (Concurrent)

WEDNESDAY, 9:30 A.M., JANUARY 26, 1955

SIERRA ROOM, HOTEL STATLER

The session was called to order by the new President of the California Mosquito Control Association, Mr. Thomas M. Sperbeck, Manager, Sutter-Yuba Mosquito Abatement District.

Mr. Sperbeck: Will the districts in the four regions of the California Mosquito Control Association plan to meet and select their regional representatives and give these names to our secretary, Mr. Washburn? Some have done that and I'm reminding the others to meet and do so, then notify us of your selection. Are there any announcements before we start today's session? If not, I want to introduce the chairman of the symposium who will carry on for the forenoon session and who will, in turn, introduce the panel, Dr. Robert Metcalf of the University of California at Riverside.

Dr. Metcalf: Thank you very much, Mr. Chairman. As you see by the program, this session is devoted to what we have generously titled a "Symposium on the Chemical Control of Mosquitoes."

The chemical control of mosquitoes certainly continues to be a subject that is greatly relied upon for mosquito control measures, but it is one which is in a continuous state of flux. This is brought about by the continuous progress of the chemical industry in bringing new materials into experimental use and also by the ability of mosquitoes to circumvent our best means of control with such mechanisms as resistance.

A brief comment about the development of new materials might be in order here. I personally feel that the greatest drawback in developing new materials which will enable us to keep abreast with resistance lies in their difficulty of introduction. It's not particularly hard for the organic chemist to synthesize new organic compounds which will show a great deal of promise for the control of mosquitoes. As an illustration of that, we have tested in our screening programs at the University of California at Riverside during the past 4 or 5 years nearly 4,000 compounds against mosquitoes. Literally hundreds of these compounds are quite toxic to mosquito larvae and conceivably could be developed as new and promising larvicides. From this program have come such materials as EPN, Chlorthion, and Malathion. I don't mean that we have been the only ones to discover their properties, but they have shown up as unusually promising and have graduated into the field as mosquito control agents. However, the difficulty seems to arise in proving that these chemicals can be used safely, not only by the mosquito control operator, but that they can be applied where domestic animals are quartered and grazed, actually to crops whose consumption will be by man or animals without deleterious effects. That seems to be the stumbling block we have at the moment.

With the passage of the Miller Bill, the Food and Drug, and other regulatory agencies, we are finding it necessary to find more and more detailed information about the chronic toxicity of these new chemical compounds. The burden now is on the manufacturer to provide evidence that these compounds can be used without undesirable effects. It now is required that 2 year chronic feeding studies be carried on before any compound can be considered for registration. This means that by the time the chemist in the laboratory has developed a promising compound, the entomologist has tested it in the laboratory and found it is highly toxic to mosquito larvae, and that a few field tests have been made which shows it better than anything we now have, it is still going to be 2 years, assuming all goes well, before the compound can be used commercially. When you know that it takes 2 years for a mosquito to develop resistance to a compound, once it has been overly applied, you can see what we are up against. I know of no way to circumvent or short-cut this thing. It's the law; it's legal; and it's reasonable. None of us want to be a party to any type of activity whereby the nation's health might be harmed in the slightest.

We all know there are no cases, on record, of misuse of chemicals, when properly applied from the residue standpoint of injuring the nation's health. What this means, in short, is that we need more basic investigations of the behavior of this chemical, more laboratories engaged in developing methods of residue analysis—often one of the bottlenecks. We need more biochemists at work to learn what happens to these chemicals when they are ingested by mammals and when they are applied to food stuffs. This is particularly interesting because the Food and Drug agencies are becoming more and more curious, not only about the chemical, as applied, but modifications of it which occur to it under the influences of enzymes in the plant, the action of sunlight, etc. I merely present this picture to indicate to you why the chemical control of mosquitoes is not as rapid as we all desire.

The further point that occurs here is the gamble the manufacturer of new chemicals must take before he can introduce them to the public. It has been estimated by reliable individuals that it may cost from one-half million to 2 million dollars to put a new agricultural chemical on the market. You can readily see that unless there is a guarantee of a good market, the manufacturer cannot profit sufficiently to make it desirable to market certain of these new chemicals, and that is particularly true here. If a chemical has only a specific use as a mosquito larvicide, is there sufficient market for it to go through all this elaborate 2-year ritual, we might call it, in order to get it registered?

With those thoughts we will turn the program over to the 4 speakers who very kindly consented to come here, most of them from considerable distances, to present this program for us. We have tried to cover the field of chemical control of mosquitoes from as many different standpoints as possible, using outstanding speakers from various agencies who are basically engaged in the process of chemical control of mosquitoes. The first paper on the program, "The U. S. Army Program of Chemical Control of Mosquitoes" by Austin W. Morrill—(paper published elsewhere).

CHEMICAL CONTROL OF MOSQUITOES IN THE TROPICS[1]

Archie D. Hess, *U.S.P.H.S.*
Logan Field Station, Utah

Mosquito control in the tropics is concerned primarily with those species which transmit disease. Pest mosquito control is a luxury which most tropical countries cannot yet afford. The mosquito-borne diseases of the tropics include malaria, yellow fever, dengue, filariasis, and encephalitis. Of these, malaria is by far the most important. It has been estimated that of the approximately 2.5 billion people living on the earth, 250 million have clinical attacks of malaria and 2.5 million die of the disease each year (Pampana and Russell, 1955). In India alone 75 million people have malaria each year, 800,000 die from the disease, and an equal number die from the indirect effects. In epidemic years these figures may be doubled (Singh, 1953).

EXTENT OF MOSQUITO CONTROL ACTIVITIES IN THE TROPICS

The various programs directed at the anopheline vectors of malaria constitute the major mosquito control effort in the tropics at the present time. These programs are generally of three types, depending upon the degree of outside support: (1) Programs carried out independently by individual countries; (2) international-assisted programs; and (3) bilateral-assisted programs.

The National Malaria Eradication program in the United States (Andrews, et al., 1954) and the nationwide campaign against malaria in Venezuela (Gabaldon and Berti, 1954) are examples of independent national programs. The United States program reached its peak in 1948, when over 1 1/3 million dwellings in 13 states were sprayed with DDT. Within five years malaria was almost eradicated, and the chief concern at the present time is with imported malaria. In Venezuela almost 600,000 houses with a population of over 2¼ million people were protected by DDT residuals by the end of 1953; malaria has been eradicated from a large segment of the country, as has *Anopheles darlingi*, the most important vector of the Neotropic Region.

International-assisted programs have received major support from two agencies of the United Nations; namely, WHO and UNICEF (Pampana and Russell, 1955). WHO has given outstanding technical assistance and training through its advisory teams and malaria-control demonstration teams. In 1953 WHO-assisted projects were being carried out in some 30 countries distributed throughout the tropics and provided direct protection to about 6½ million people. UNICEF has often cooperated with WHO in providing equipment and supplies for malaria control programs. A program for eradication of malaria in the Americas has been receiving preferential attention by the Pan American Sanitary Bureau, Regional Office, WHO. About three-fourths of the 135 million people living in malarious areas of Latin America now have been protected by mosquito control operations. Malaria already has been eradicated from extensive areas in Argentina, Chile, Ecuador, Venezuela, British Guiana, French Guiana, Trinidad, and Puerto Rico (Alvarado, 1954).

[1] From the Communicable Disease Center, Public Health Service, Department of Health, Education, and Welfare, Logan, Utah.

The United States has been the chief contributor to bilateral-assisted malaria control programs through the Foreign Operations Administration (FOA), and its predecessors, MSA, TCA, and ECA. In 1953 FOA-assisted malaria control projects brought protection to 124 million people in 17 countries (Price, 1954). Many of the FOA-assisted programs are nationwide in coverage, as for example, in the Philippines, Thailand, and India. The program in India (Singh, 1953) is by far the largest malaria project ever undertaken; its current objective is the protection of 125 million people, and it may eventually be extended to protect the entire 200 million individuals living in malarious areas of India.

Aedes aegypti control measures directed against urban yellow fever and dengue rank next to malaria control in present day mosquito control activities in the tropics. Of particular note is the campaign for the eradication of *Aedes aegypti* in the Americas, for which the Pan American Sanitary Bureau provides leadership, coordination, and technical assistance (Severo, 1952). Recent outbreaks of jungle yellow fever in Central and South America have stimulated interest in this eradication program. Of the 21 countries concerned, 9 have the campaign completed or in final stages; 8 have the work in progress; 2 are starting it; and only 3 (United States, Cuba, and Haiti) have not yet started. Urban yellow fever has to all intents and purposes been nonexistent in Africa for several years; however, jungle yellow fever still persists and offers a constant potential threat of re-infection of urban areas where *A. aegypti* is present (WHO, 1954).

Filariasis is widely distributed throughout the tropics, and various countries direct mosquito control operations at the species of *Culex, Aedes, Anopheles,* and *Mansonia* which are vectors of the disease. Control of these vectors also has been of concern to military forces operating in endemic areas, such as the islands of the South Pacific. In some countries, as for example Thailand, combined mosquito control operations are directed at both malaria and filariasis (Griffith, 1954).

In addition to the national and international mosquito control programs discussed above, the Military carries out intensive mosquito control operations at its various installations located in tropical countries.

FACTORS AFFECTING CHEMICAL MOSQUITO CONTROL IN THE TROPICS

Certain climatic and socio-economic factors affecting chemical mosquito control in the tropics are different from those in temperate regions. The high temperatures and humidities of the tropics affect the residual properties of mosquitocidal applications and cause a more rapid deterioration in concentrate formulations. Rainfall patterns rather than temperatures often determine the seasonal population densities of the mosquito vectors, and the deluges which accompany the monsoon seasons make roads impassable, and thus limit control operations to the dry season. The warmer climate may result in longer seasons of production, and mosquito breeding and disease transmission may often be perennial.

The prevailing types of human habitations in the tropics are constructed of porous and absorbent materials such as mud, bamboo, and nipa palm; this affects the type of formulations and duration of residual sprays. The structure of the houses also provides special types of resting places for mosquitoes, as for example the crevices of thatched roofs and the under sides of nipa huts on bamboo "stilts." The habits of the mosquitoes themselves may be important; for example, *Anopheles pseudopunctipennis* resting beneath the ridgepole of high thatched roofs in Mexico may require a long extension wand for spraying; whereas, the low resting habits of *Anopheles minimus flaviorostris* in the Philippines may require that special attention be directed at the lower half of the walls and the surfaces beneath the house. The biting-resting habits of the mosquito vector are of special importance in the applicability of residual spraying techniques. On this basis Gabaldon (1953) has classified adult anophelines into four groups: (1) outdoor-biters and outdoor-resters; (2) indoor-biters and indoor-resters; (3) outdoor-biters and indoor-resters; and (4) indoor-biters and outdoor-resters.

The morés or local customs of the people frequently have a direct effect upon mosquito control in the tropics. For example, the custom in Ceylon and India of replastering the mud walls of houses several times a year (Dy, 1954) covers up insecticidal residues and may require more frequent application of sprays. The housewife's practice of frequent scrubbing of the walls, as in parts of the Philippines, removes the spray residual and shortens the life of the treatments.

Many countries of the tropics are still underdeveloped, and the low economic levels place a direct limitation on the kind and extent of mosquito control measures which can be carried out. Programs which are economically feasible for Venezuela and Sarawak may be completely out of reach for India or Uganda.

METHODS AND MATERIALS IN CURRENT USE IN THE TROPICS

Methods of Control

Residual spraying of houses is the primary method used in malaria control programs throughout the tropics. However, larvicides are still used in some areas. For example, in Malaya residual insecticides are used to combat rural malaria carried by *Anapheles maculatus,* but larvicides are used for urban malaria control (Anderson, 1954). In the Jordan Valley the use of larvicides has been recommended to control local malaria vectors such as *Anopheles sergenti,* which bite in the open and rest in unsprayed caves and fissures, thus avoiding contact with sprayed premises. The outstanding example of an outdoor-biter unaffected by residual house sprays is *Anopheles bellator* in Trinidad, B.W.I., which transmits malaria during the daytime by biting workers in shaded cocoa plantations, or during the evening on open verandas. However, in this instance control is achieved by the use of copper sulphate to control the epiphytic bromeliads (principally *Gravisia aquilega*) which provide the aquatic habitat for the *bellator* larvae (Downs and Pittendrigh, 1946). Another example of mosquito abatement through plant control is in Ceylon where mechanical and herbicidal clearance of water lettuce *(Pistia stratictes)* is used to control *Mansonia* mosquitoes, the local vectors of rural filariasis (Chow, 1953).

Although residual sprays are playing the major role in world-wide malaria control, drainage and other permanent improvement or source reduction procedures are still important in many countries, particularly with regard to long-range programs. For example, in the six-year Philippine-American malaria control program residual sprays are being used to "knock malaria down," but permanent measures are considered important in the long-range program to "knock malaria out" (Ejercito, et al., 1954). Permanent measures have played an important role in the Venezuelan program, and it was by the use of drainage that *Anopheles darlingi*-transmitted malaria was first eliminated from several towns (Berti, 1945). Cuba also continues to stress drainage and antilarval measures.

Both larvicidal and adulticidal sprays are used in the campaigns against *Aedes aegypti,* treatments being made in three ways: (1) intradomicile spraying similar to that used for malaria control; (2) larviciding of water receptacles; and (3) perifocal or preferential spraying in which all inside and outside water receptacles are sprayed, with or without water, also adjacent walls or other adult resting places (Severo, 1952). From an overall standpoint of economy and effectiveness, the perifocal method is preferred.

Insecticides

DDT is still the chief insecticide used for mosquito control in the tropics. The 14 countries participating in the First Asian Malaria Conference in Bangkok in 1953 reported a predominant use of DDT in their residual spraying operations (Dy, 1954). In the antimalaria campaign in the Americas over 90 per cent of the sprayed surfaces have been treated with DDT (Alvarado, 1954). BHC has been shown to be an effective residual spray for anopheline control, but its greater volatility and consequent shorter duration has limited its use. Increased effectiveness has been reported from the use of DDT-BHC combinations (Sharma and Pal, 1952). Dieldrin has been used experimentally and in pilot projects in various countries. Indications are that it may be more effective than DDT against the complex of species which transmit filariasis in various parts of the tropics. It has been reported that *Culex fatigans,* a common filaria vector, has been eradicated at Fort Island, British Guiana, by two residual applications and combined larvicidal use of dieldrin (Charles, 1954). This species is frequently found to be refractory to DDT. Dieldrin also is being used increasingly in Central and South America for the combined control of mosquitoes and the triatomid vectors of Chaga's disease (Penalver and Villagran, 1955). Chlordane has been used to some extent, such as in situations where combined roach and fly control also is desired (Berti, 1954).

The relative effectiveness of DDT, BHC, and dieldrin residual sprays for control of adult mosquitoes has been related to their irritant-repellant effects. DDT is reported to be most irritant, and dieldrin the least; BHC was found to be highly irritant when solid, but not when vaporized (MacDonald and Davidson, 1953). The same workers maintain that DDT provides the 65 per cent mortality required for controlling moderate malaria transmission by endophilic species, but that in severe conditions where 85 per cent mortality is required, it is necessary to use BHC or dieldrin.

Various other insecticides have been used for experimental mosquito control in the tropics, including the newer organic phosphorus compounds.

Types of Formulations

Water wettable powder has been the formulation in predominant use for malaria control in the tropics because of the predominance of mud, grass, palm, bamboo, and other absorbent surfaces in human habitations. Considerable difficulty has been experienced in several tropical countries from the deterioration of DDT water wettable formulations (Johnson, 1953). This deterioration has resulted in loss of suspensibility properties and in some instances, there has been an actual chemical deterioration of the DDT by dehydrohalogenation to DDE (Quarterman, 1955). Difficulty was also experienced with early water wettable formulations of dieldrin which were manufactured for agricultural use in power-spraying equipment and did not have adequate suspensibility for hand-spraying equipment. For this reason several experimental dieldrin programs failed; for example, a large scale dieldrin house spraying experiment in Sumatra (Johnson, 1953), and a dieldrin pilot project in the Philippines. Subsequently, a very excellent 50 per cent water wettable dieldrin formulation has been developed and has been used and found satisfactory in various field tests. WHO and FOA, with the cooperation of the U. S. Public Health Service, and the U. S. Department of Agriculture, have sponsored the development of improved specifications for DDT formulations, and very satisfactory 75 per cent DDT water wettable formulations are now available. WHO also has sponsored research on the interaction between insecticides and the walls (particularly mud) upon which they are sprayed, and institutes in various parts of the world are collaborating in this study (Pampana and Russell, 1955).

Emulsions and solutions are still used to some extent in residual spraying operations, particularly where a better grade of housing is involved. Both 75 per cent DDT water wettable powders, and 25 per cent DDT water emulsifiable concentrates are used in *Aedes aegypti* control operations.

The military uses various formulations for mosquito control. For example, the Navy uses 25 per cent DDT emulsifiable concentrates, 75 per cent DDT water wettable powders, and 20 per cent DDT airplane spray (Knight, 1955). The latter is frequently diluted with No. 2 diesel oil for use in fog machines and for larviciding. In general, the military makes more extensive use of airplane spraying and does more general purpose vector control, including the control of pest mosquitoes.

Dosages and Spray Intervals

The application of DDT residuals once a year at the rate of 200 milligrams per square foot (or its approximate equivalent of 2 grams per square meter) is the most widely used regimen for malaria control in the tropics. Modifications of this regimen are carried out in various countries. In Ceylon, where walls are frequently replastered, dosages of 60 mg./sq. foot may be applied five or six times a year; in Portuguese India 50 to 150 mg. four times a year; in India 50 mg. once or twice a year; and in Sarawak DDT is applied twice a year; BHC four times a year (Dy, 1954). In the antimalaria campaign in the Americans, most applications are made once a year, although some smaller countries continue to spray twice a year (Alvarado, 1954). A dosage of approximately 2 gm. DDT per square meter applied every six months has been recommended for Africa (MacDonald, 1953).

BHC dosages have usually ranged from 0.05 to 0.5 gms. gamma isomer per square foot with effective treatment intervals from a few weeks to several months (MacDonald and Davidson, 1953).

Dieldrin is usually applied at rates of 25 or 50 mg. per square foot. A pilot project is under way in the Philippines to determine if the 50 mg. dose may remain effective for 2 years. In some situations 200 mg./sq. ft. residuals of DDT have been found to remain effective for longer than one year, as for example, against *Anopheles aztecus* in Mexico, and *A. minimus* in Thailand.

Various techniques have been investigated for reducing dosage without decreasing effectiveness. These include spraying of alternate houses (Thailand), selective spraying of surfaces within houses (Formosa), "strip spraying" (Lebanon), and reducing dosage from 200 to 100 milligrams (Thailand). Although some of these procedures have been used satisfactorily, the general tendency has been to lean on the side of thorough coverage with adequate dosage. This also has important implications with regard to the development of resistance, which will be discussed in the next section.

In the anti-*Aedes aegypti* campaign DDT is applied so as to give a residual of 2 gms. per square meter on sprayed surfaces, or a concentration of 2 parts per million in water (Soper, 1955). Dieldrin is being used experimentally at a rate of 0.6 gms. per square meter.

MOSQUITO RESISTANCE TO INSECTICIDES IN THE TROPICS

The problem of insecticide resistance is becoming increasingly important with regard to mosquito control in the tropics (Hess, 1953). Initially this was considered a problem only with regard to culicines. The *Culex pipiens* complex was one of the first and the most widespread group to show evidence of DDT resistance. This has, in many instances, apparently been due to the fact that this species is inherently refractory, or naturally resistant to DDT. However, there have been various examples of acquired resistance since 1947 when *Culex pipiens autogenicus* was first reported to be resistant toDDT in Italy. The development by *Culex fatigans* of resistance to BHC in control areas of Malaya has recently been demonstrated (Reid, 1954).

More recently there has been a growing concern over the development of resistance in anopheline vectors of malaria (Pampana and Russell, 1955). This has varied from a behavioristic type of resistance in *Anopheles sergenti* in the Jordan Valley (Farid, 1954), and *A. albimanus* in Panama (Trapido, 1954) to a definite acquired physiological resistance in *A. sacharovi* in Greece, (Belios, 1954), and the Levant (Garrett-Jones and Gramiccia, 1954), and in *A. sundaicus* in Java (Crandell, 1954). In the latter instances the resistance has developed to a level where it is definitely interfering with the effectiveness of malaria control operations. Whereas it was originally believed that the exophilic habits of *A. minimus flavirostris* in the Philippines would prevent its effective control by DDT residual house sprays, a cooperative project by WHO and the Philippine and United States Governments has recently provided conclusive evidence that malaria transmitted by this species can be controlled by yearly applications of DDT at 2 grams per square meter (Pampana and Russell, 1955). Careful observations frequently reveal that a species of *Anopheles* has greater contact with the inside walls of houses than was previously suspected, as for example, recent studies with the *A. punctulatus* group and *A. karwari* in Netherlands New Guinea (Van Thiel, 1954).

As in the early days of DDT-resistant flies, there are conflicting reports with regard to cross resistance to other chlorinated hydrocarbons by DDT-resistant anophelines. Dieldrin is reported to be effective against DDT-resistant *Anopheles sundaicus* in the Djakarta coastal area of Java (Crandell, 1954); on the other hand, DDT-resistant *A. sacharovi* in Greece are said also to be resistant to dieldrin where this insecticide had not previously been used (Belios, 1954, A). If the pattern of resistance development in *Anopheles* is similar to that which has occurred with flies, other chlorinated hydrocarbons will only have very transitory usefulness against DDT-resistant species.

The increasing development of insecticide resistance calls for a change in strategy in mosquito control in the tropics, particularly with regard to malaria control. Any measures which result in spotted or sublethal dosages of insecticide should be discouraged, and emphasis should be placed on thorough and adequate coverage over large areas. This means that such techniques as "strip spraying," alternate spraying of houses, and reduction of insecticide dosage wherever possible. Also, as recommended by the Second Asian Malaria Conference which met at Baguio in the Philippines November 15-17, 1954, "The use of chemically related insecticides against both adults and larvae should not be carried out simultaneously in the same area, except in cases of emergency." As has been pointed out by Pampana (1954), control programs should be directed toward thorough coverage over large areas with the objective of eradicating malaria before anopheline resistance develops. It is no longer logical to think of the use of residual sprays as a continuously recurring operation, like the chlorination of water supplies, and full consideration should be given to the interruption of area-wide spraying operations when a satisfactory end-point in malaria control has been achieved.

THE FUTURE OF MOSQUITO CONTROL IN THE TROPICS

The world-wide elimination of malaria as a public health problem is technically feasible within the next decade, and it is not unreasonable to expect that the disease may eventually be completely eradicated. Such eradication of mosquito-borne diseases should be the primary goal of mosquito control in the tropics. This goal can only be achieved through international effort, through the continued leadership and cooperative endeavor of WHO, FOA, and the many devoted and capable workers in the countries throughout the tropics where mosquito-borne diseases are prevalent.

As mosquito-borne diseases are brought under control, the scientific disciplines and experiences may be turned to the control of other disease vectoring arthropods, and subsequently to other blood-sucking arthropods which interfere with the health and welfare of mankind. Thus, mosquito control organizations may logically be expected to metamorphose into vector control organizations.

Lastly, it is imperative in our pre-occupation with control operations that we do not fail to recognize the importance of and to provide continued support for fundamental and applied research. Mosquito control will never be a static activity, and research provides the life blood for progressive and continuous development of more effective and less costly methods to meet the ever changing needs.

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RESULTS OF 1953-54 FIELD TESTS WITH INSECTICIDES FOR CONTROL OF MOSQUITOES IN OREGON

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In 1953 and 1954 field tests with various insecticides against larvae and adults of snow-water and floodwater *Aedes*—mostly *A. communis* (DeG)., *hexodontus* Dyar, *fitchii* (Felt and Young), *sticticus* (Meig.), and *vexans* (Meig.)—were conducted in the Cascade Mountain and Columbia River areas of Oregon. In all these tests DDT was also used as a standard of comparison.

LARVICIDES.

Chlordane and Heptachlor. Tests against the larvae were made with these insecticides in the form of emulsions, oils, and granules. The liquid formulations were applied with a trombone-type sprayer at the rate of 4.6 quarts per acre, and the concentrations were varied to give different dosages of the insecticide. The granular material contained 2.5 to 5 percent of the insecticide and was broadcast by hand.

The data presented in Table 1 demonstrated heptachlor to be similar to DDT in toxicity to larvae of the non-resistant *Aedes* of the snow-water and floodwater complexes. Chlordane was the least effective material when applied in any form at 0.05 pound or less per acre, but when applied in an emulsion at 0.1 pound on snow-water larvae or at 0.2 pound per acre on floodwater larvae it provided 99 to 100 percent control.

Granular preparations of chlordane and heptachlor gave mortalities similar to those obtained with emulsions of the same insecticides. Although the granular materials presented some difficulty in distribution because of the small amount required, the results indicate that the water throughout the pools was uniformly toxic during the 24-hour test period. In situations having heavy emergent foliage or brush the granular material was found to be particularly convenient to use, as it penetrated to the water's surface with negligible adherence to the foliage.

EPN. Gjullin (1953) showed EPN to be highly effective against resistant *Culex* larvae in California. However, field tests in log-pond situations in Oregon on non-resistant *Culex tarsalis* and *Culiseta incidens* larvae have indicated little difference between EPN and DDT. Yates (1952) demonstrated in laboratory tests that the effectiveness of EPN varied with the species of mosquito.

As larvicides for snow-water and floodwater mosquitoes, EPN and DDT were applied in emulsions as in the previous tests. Water temperatures in the snow-water plots were 40° to 44° F. and in the floodwater plots 60° to 62° F.

Table 2 shows that EPN caused similar mortalities of both *Aedes* complexes at most dosages and that DDT gave results approximating those of EPN. The similarity of the results with these two insecticides under Oregon conditions indicates that a low species susceptibility plus low temperature tends to reduce the effectiveness of EPN while increasing the effectiveness of DDT. Thus it appears that in cool areas where resistance is not a factor there would be little advantage in using EPN instead of chlorinated insecticides.

ADULTICIDES.

Lindane and BHC, With and Without Chlorinated Terphenyl. Recent studies by Hornstein and Sullivan (1953-1954) have indicated that the residual effectiveness of Lindane or BHC can be extended by the addition of a chlorinated terphenyl (Aroclor 5460). Those workers furnished several formulations for evaluation against snow-water *Aedes* in comparison with the insecticide alone. These formulations contained 27.8 percent each of either lindane or high-gamma (40 percent) BHC and chlorinated terphenyl in the highly volatile solvent methylethyl ketone. They were applied undiluted, as it was believed that in the small droplets of a highly concentrated spray the insecticide would be more effectively bound by the chlorinated terphenyl. However, because of the sparse coverage obtained with very small amounts of the concentrated solutions, a dilute spray was included in the tests in order to insure better coverage. The sprays were applied on 1-acre plots with a Potts-Spencer mist blower that could be carried on the back over rough mountain terrain.

Mosquito populations were determined from 1-minute landing counts on the trousers of two men. Ten counts per man were recorded in each plot. Counts were made before and after treatment in both treated and check areas. As nearly as possible counts in any one area were taken at the same time each day.

TABLE 1—*Effectiveness of several formulations of heptaclor, chlordane, and DDT against snow-water and floodwater Aedes mosquito larvae. 2 to 5 replicates.*

Dosage (pound per acre)	*Percent mortality in 24 hours*							
	Heptachlor			*Chlordane*			*DDT*	
	Emul.	*Oil*	*Gran.*	*Emul.*	*Oil*	*Gran.*	*Emul.*	*Oil*
Snow-water *(Aedes communis, fitchii,* and *hexodontus)*								
0.0125	81	65	87	43	27	49	91	68
.025	95	81	94	70	43	59	99	84
.05	100	99	99	78	78	68	99	99
.075	—	—	100	—	—	88	—	—
.1	100	100	—	99	85	—	100	100
Floodwater *(Aedes vexans, sticticus,* and *cinereus)*								
0.0125	85	—	—	50	—	—	75	—
.025	98	—	88	70	—	83	96	—
.05	100	—	95	91	—	85	96	—
.075	—	—	100	—	—	97	—	—
.1	98	—	—	88	—	—	92	—
.2	100	—	—	100	—	—	99	—

TABLE 2—*Effectiveness of EPN and DDT in emulsions against snow-water and floodwater Aedes mosquito larvae. 3 or 4 replicates.*

Dosage (pound per acre)	*Percent mortality in 24 hours*			
	Snow-water		*Floodwater*	
	EPN	*DDT*	*EPN*	*DDT*
0.00625	42	—	30	—
.0125	82	91	44	75
.025	90	99	92	96
.0375	94	—	—	—
.05	100	99	94	96
.075	—	—	100	—

TABLE 3—*Residual effectiveness of lindane and BHC alone and with chlorinated terphenyl in comparison with DDT against snow-water Aedes mosquitoes.*

Formulation[a] *(figures indicate pounds of active ingredient per acre)*	*Milliliters of spray per acre*	*Per cent reduction after —*				
		1 day	*2 days*	*5 days*	*10 days*	*15 days*
BHC (40% gamma) 0.2						
Alone	719	51	61	38	—	—
Plus chlorinated terphenyl	719	44	26	25	—	—
	4000	82	69	79	[b]	—
Lindane 0.2						
Alone	719	77	78	60	—	—
	4000	75	42	57	41	—
Plus chlorinated terphenyl	719	50	23	0	—	—
	4000	78	46	80	46	—
Lindane 1.0						
Alone	1500	99	88	98	76	88
Plus chlorinated terphenyl	1500	97	83	63	75	52
Lindane 0.5 in Shell 42[c]	1500	95	95	85	[b]	—
DDT 0.2						
In methylethyl ketone	1800	93	—	95	84	—
In No. 2 fuel oil	1800	97	87	84	91	[b]
	4000	98	65	71	[b]	—
DDT 0.5						
In Shell 42[c]	1500	88	90	88	[b]	—
1.0 in No. 2 fuel oil	1500	88	82	89	30(?)	94

(a) Methylethyl ketone was solvent in all BHC and lindane formulations unless otherwise indicated.
(b) Insect activity nil in both treated and untreated plots.
(c) An aromatic solvent.

As shown in Table 3, the chlorinated terphenyl did not improve the control obtained with lindane or BHC alone, either immediately or as a prolonging agent. In fact, in paired tests with the concentrated sprays at the rate of 0.2 pound of insecticide to the acre greater reductions were recorded for a longer period with sprays containing lindane or BHC alone. When the concentrate was diluted to 4000 ml. there was no significant difference between formulations that did or did not contain the terphenyl. Furthermore, there was some indication that the concentrated sprays were inferior to the diluted ones.

One paired test in which Lindane was applied in concentrated form at a rate of 1 pound to the acre showed at least 97 percent reduction both with and without the terphenyl for 24 hours, but thereafter lindane alone provided the higher control through 15 days of observation.

In comparative tests DDT in methylethyl ketone or fuel oil provided control equal to or better than lindane at the same rates.

Methylethyl ketone was found to be irritating to the skin of the spray operator, and because of its high volatility in the concentrated solutions considerable lindane crystallized out on the spray head.

Malathion and Chlorthion. Because of increased interest in organic phosphorus chemicals as larvicides and more recently in aerosols for adult control, some of these materials were tested as residual treatments against snow-water *Aedes*. As a preliminary test two 1-acre plots in the mountain area were sprayed with a mist blower with 4000 ml. of an emulsion containing 1 pound of either Malathion or Chlorthion per acre. Neither spray gave the immediate knockdown that has been experienced in spraying mountain plots with other materials, nor was the reduction particularly high after 24 hours. However, Malathion gave a greater reduction (71 percent) than Chlorthion (32 percent). After 5 days the two materials gave 82 and 89 percent control, but thereafter control was negligible. Thus it is indicated that when applied at the rate of 1 pound per acre, Malathion and Chlorthion are inferior to the chlorinated hydrocarbons as residual applications to foliage for the control of mountain *Aedes*.

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CHEMICAL CONTROL OF MOSQUITOES IN CALIFORNIA

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We have now been using the so called newer insecticides in mosquito control for 8 years, and it seems both timely and pertinent to review the history of usage during this period.

There has been such a wide range and variation in the use of toxicants and methods of application in the 53 mosquito control agencies in California that time here will just not permit coverage of the field. I might state, in addition, that it would perhaps require six months of real work to get all of the necessary data compiled and properly evaluated. Therefore, I will attempt to cover in detail a history of the use of insecticides in the Kern Mosquito Abatement District from 1945 up to the present time, and then generalize on trends in the various regions of the state.

First, for the benefit of those who are not familiar with mosquito control in California, I should point out that the use of insecticides in California is primarily as larvicides and, secondly, as adulticides applied as aerosol or spray. Little control is attempted by the residual spray technique for control of adult mosquitoes.

It was about May or June of 1946 that DDT first became available to the Kern District in any quantity. At that time a considerable amount was purchased from the War Assets Administration. This original purchase was emulsifiable DDT, and although the formulation was not known, its water stable characteristics proved it to be very satisfactory for most conditions encountered in the district. This material used as a larvicide was applied as a water emulsion by hand and power pumps and by airplane spraying at an average rate of approximately .33 lbs. per acre at volumes ranging from 1 gallon to 10 gallons per acre.

Dry dust was tested by ground application with a Root power duster; but, at even relatively heavy dosages, results were not generally satisfactory. A 3% dry dust at 4-6 lbs. per acre also was tried by airplane application that season, but again results were highly unpredictable.

Also attempted in 1946 was a method of controlling *Aedes* species by a so called "drip" system. That is, by introducing the emulsifiable concentrate directly into the stream of irrigation water. This was first attempted on several duck ponds, and although a great deal of mechanical difficulty was encountered in early trials, results were very encouraging; and it was decided to attempt control in this same manner on a larger scale the following season.

Oil solutions of DDT were tested by airplane, hand, and ground equipment; but results as obtained in Kern County indicated no advantage over the emulsions either toxically or economically. Therefore, following repeated trials with oil solutions during 1946 and again in 1947, this district discontinued the use of oil solutions as being less satisfactory than emulsifiable DDT.

For the 1946 season, the district used 3,233 lbs. of DDT, applied at an average rate of .33 lbs. to the acre. Emulsifiable form came to be the preferred material and the most commonly used; however, dry dust, wettable dust, and oil solutions were given extensive trial.

In 1947, the DDT purchased from the War Assets Administration was used until the supply ran out in August. After that, a great deal of difficulty was encountered in finding an emulsifiable concentrate with which we could obtain consistently satisfactory results. This difficulty was finally narrowed down to insufficient stability of most commercial formulations, in part due to the use of soaps as emulsifying agents.

Further tests were attempted during 1947 to control *Aedes* larvae by direct introduction of DDT into irrigation waters. Many of the mechanical difficulties of the drip system were overcome by using a syphon principle, and a suitable emulsifiable concentrate became available through a local manufacturer. Methods and rates remained about the same as finally evolved in late 1946; namely, larvicidal application of aqueous emulsions of DDT at .3 lbs. per acre. During the year, the gross quantity used amounted to 10,094 lbs.

Based on the previous years' experiences, we began the 1948 season on a very optimistic note. Larviciding methods and rates of application had become what we then thought to be well established. In addition, the many trials and improvements developed on the drip system during 1947 culminated in the adoption of this larviciding technique as a permanent method of control on two ranches near Bakersfield in 1948. One of the ranches covered 557 acres; the other, 200 acres. Complete control of larvae was obtained on these ranches so long as the DDT was applied into the irrigation water at a rate no less than .15 ppm. No residual action was obtained at this dosage. After DDT had given satisfactory results at .15 ppm. for several months, a failure was noted. The dosage was then increased to .2 ppm. and later to .25 ppm., but still failed to kill first and second instar larvae. The field was then sprayed by airplane at .4 lbs. per acre, but again failed to kill even first stage *Aedes* larvae. I think it is of interest to mention at this point that it seemed to us that .4 lbs. per acre was an excessive dosage of DDT.

In the light of our past experiences, it now seems reasonable to assume that this ranch would logically be the first to indicate resistance, as many applications were made at sub-lethal or minimum lethal dosages. Fortunately, we had been testing other toxicants during 1947 and 1948. Among these, toxaphene seemed most promising. When resistance to DDT appeared on the aforementioned ranches, toxaphene was tried and proved highly successful. It then became the larvicide used on these ranches during the remainder of 1948. During that year, the district used 9,796 lbs. of DDT at .29 lbs. to the acre.

In 1949 resistance appeared at a few other locations where the drip system of larviciding had been employed, and it was during this year that such larvicidal treatment was abandoned. DDT resistance seemed to be appearing at additional widely scattered locations where only the standard spray applications had been carried on. As a consequence, toxaphene replaced DDT as the preferred insecticide in those portions of the district where resistance was encountered. In other parts of the district where DDT had not been used so extensively, such as areas recently annexed, DDT continued to be used as the standard larvicide.

Further testing of toxicants during 1949 indicated that aldrin might be successfully used as a substitute insecticide, should it be necessary. During 1949 the district used 9,321 lbs. of DDT at a rate of . 33 lbs. per acre, and 4,300 lbs. of toxaphene at a rate of .25 lbs. per acre.

In 1950, the fifth year that the district had been using chlorinated hydrocarbon larvicides, we began operations using toxaphene as the preferred insecticide. However, to further evaluate the successful trials made with aldrin the previous year, this material was used by a few selected operators during the greater portion of the season and proved to be highly satisfactory. It was late in 1950 that we experienced questionable indications of resistance to toxaphene. During 1950 the district used 6,844 lbs. of toxaphene at .25 lbs. per acre, and 2,245 lbs. of DDT at .33 lbs. per acre.

In 1951 toxaphene continued to be the primary insecticide used, even though indications of resistance to this chemical had appeared late the preceding year. However, because of this, aldrin was used still more extensively than during 1950. It was in July and early August of 1951 that serious resistance to both toxaphene and aldrin appeared in several areas within the district. To the field operators, resistance of *Culex tarsalis* seemed much more pronounced than that encountered in the *Aedes* species. While it was still possible to control *Aedes nigromaculis* larvae, the field operators were being forced more and more, as they termed it, to "turn the water white" with toxaphene before any appreciable kill of *tarsalis* could be noted.

Fortunately, laboratory and field testing had been started that season to determine as best as possible what degree of resistance was actually present in the Kern District and other areas of the San Joaquin Valley. This project was successfully completed through the cooperative efforts of the United States Department of Agriculture's Mr. Gjullin and personnel from the California Mosquito Control Association, the Bureau of Vector Control, and the Kern Mosquito Abatement District. As the season progressed and tests were completed, a better understanding of larval resistance was unfolded. The facts obtained were both interesting and alarming. Perhaps the most noteworthy of Mr. Gjullin's studies was his proof that not only were certain strains of larvae resistant to DDT, toxaphene, and aldrin but also to several of the chlorinated hydrocarbons which had never been used generally in California for mosquito control purposes. His work disclosed that existing resistance varied from several times to 1300 times normal in field-collected *Culex tarsalis*. It also was noted that an LD-50 did not always indicate what might be considered the true picture of the degree of resistance. This fact was illustrated by one strain of larvae which proved on an LD-50 basis to be 17½ times resistant to DDT, while on an LD-90 basis, resistance of this same strain was over 100 times, indicating a small percentage of the population to be extremely resistant. During September of 1951, evidence of the futility of any further control with chlorinated hydrocarbons on the various duck clubs became apparent after dieldrin was applied on one pond at the rate of 2 lbs. per acre without noticeable kill of *any* of the larval stages.

At that time we were all apprehensive concerning the prospects of next season's operations, but we had little idea of the seemingly hopeless situation which was to exist the next spring. It was then, however, that we obtained from Dr. Metcalf a half gallon sample of a new phosphate —E.P.N. This was near the close of the season, and without any preliminary laboratory testing, it was applied by airplane at the rate of .05 and .1 lbs. to the acre. Results were 100% kill on resistant *Culex tarsalis* larvae. Several more tests were made at .025 lbs. per acre and again results were 100% kill. A freeze and continued cold weather prevented any further testing for the season. During 1951 the district used 16,112 lbs. of toxaphene at .35 lbs. to the acre and 2,090 lbs. of DDT.

There was no shortage of experimental plots the following spring—1952—as thousands of acres of lowland adjacent to the Kern River were flooded by waters from the melting of a record snow pack in the mountains. *Culex tarsalis* larvae appeared throughout the entire flooded area. In an attempt to control the rampant breeding, toxaphene, BHC, DDT, aldrin, and dieldrin were all tried; but little success was experienced with any of these chlorinates, and we had to rely upon larvicidal oils, using almost 100,000 gallons through June. Aldrin was still sufficiently effective on *Aedes* species and was used for their control during this period. During the spring and early summer months, the aforementioned agencies again cooperated and completed approximately 80 experimental plots; malathion, NPD, and EPN being the principal toxicants tested. In their respective dosage categories, all appeared promising. In July our first shipment of emulsifiable EPN arrived. It was the only insecticide used for the remainder of the season and proved most satisfactory.

In conjunction with larvicidal field testing, cholinesterase activity checks were taken every two weeks on three field operators using EPN routinely, as well as on the pilot and entomologists during the testing. Over a three months period, there were no indications of inhibited cholinesterase activity in any of these men. A study also was made to determine what amount of EPN, if any, was deposited as a residue on pasture grasses. Samples were taken just before and 24 hours after application. During three months of investigations involving 6 irrigations and treatments, no phosphate was recovered. Insecticide usage during 1952 was as follows: 1400 lbs. of EPN at .075 lbs. per acre; toxaphene, 1749 lbs. at .4 lbs. per acre; aldrin, 2343 lbs. at .1 lb. per acre.

The 1953 season passed without any noteworthy evidence of resistance to EPN, the insecticide being used. Laboratory and field testing of toxicants continued through the season, indicating that chlorthion, malathion, and parathion were promising materials that might be used for mosquito control purposes. Minimum effective field application rates of these materials proved to be as follows:

EPN	.040 lbs. per acre
Parathion . . .	.050 lbs. per acre
Chlorthion . .	.15 lbs. per acre
Malathion . . .	.4 lbs. per acre

During 1953 EPN was the toxicant used at .075 lbs. per acre and a total of 2,627 lbs. were applied in the district.

In early 1954 we learned definitely that emulsifiable EPN would no longer be compounded and therefore would not be available. Unfortunately, chlorthion was not available in more than research quantities; and, although malathion was available, its application at .5 lbs. per acre would have cost over a dollar per acre, or more than double the cost of applying EPN at .075 lbs. per acre. EPN was still available in wettable dust, but our spray units were not equipped with mechanical agitation. Parathion was available in unlimited quantities and was comparatively inexpensive; however, there was a general feeling of reluctance in placing it into the hands of 25 to 30 operators. Considering all factors involved then, it appeared that the most logical move would be to equip our spray equipment with fluid agitation for using wettable EPN and use emulsifiable parathion in the airplane. These formulations were used all during the season without any serious misgivings. The wettable EPN, while being a satisfactory toxicant, was very undesirable to use. The fluid agitation left something to be desired in keeping the dust in aqueous suspension, and the dust proved very abrasive on pump parts and nozzles. As a consequence, we do not intend to use the dust next year.

As of the present, we are not certain what insecticide we will use next year. If chlorthion is available at a competitive price, we will most likely use it in our ground equipment because of its low mammalian toxicity. If it is not available at a reasonable cost, it seems most probable that we will use parathion in both ground equipment and airplane spraying. We will not place it into the hands of our field operators, however, until all necessary adjustments are made for safe handling of the emulsifiable concentrate.

In summarizing the use of insecticides in the Kern District from 1945 to the present time, we find that DDT was used as a larvicide in emulsifiable form at an approximate rate of .25 to .33 lbs. per acre, beginning in 1946, and its use was discontinued generally in 1951.

The first resistance to DDT appeared in late 1948 in a few selected locations. Thereafter, resistance to this chemical gradually spread throughout the district during 1949 and 1950 as well as becoming much more pronounced.

Aqueous emulsions of toxaphene were first used as a larvicide when substituting for DDT in a few selected locations during the late 1948 season. This material, applied at .33 lbs. per acre, gradually took the place of DDT during 1949 and largely supplanted DDT during 1950 and 1951.

In addition to toxaphene, aldrin also was used to some extent during 1950 at .1 lbs. per acre. It was late 1950 when the first indications of questionable resistance to toxaphene appeared. During the first half of 1951 both toxaphene and aldrin were being used until mid season, when resistance to both materials began to appear. It was in the fall of 1951 that applications of dieldrin proved ineffective, and the testing program showed a high degree of resistance to chlorinated hydrocarbons not previously used.

In all, a gross of 36,779 lbs. of DDT were used during 1946 through 1950; a gross of 29,005 lbs. of toxaphene during 1948 through 1951; and a gross of 2,433 lbs. of aldrin during 1950 through 1952. This amounted to a total of 68,217 lbs. of chlorinated hydrocarbons used by the district from 1945 through 1952, when such a high degree of resistance had been developed to all chlorinated hydrocarbons that they could no longer be used effectively.

During 1952, '53, and '54, the phosphate, EPN, has proven to be a highly effective insecticide; and this past season, parathion has proven exceptionally good, but our use of it has been limited to aerial application.

Experiences of other mosquito control agencies in California have not necessarily followed the same pattern as that outlined for the Kern District. Yet there has been somewhat the same trend in use of toxicants, particularly so on a regional basis.

These regions where ecological conditions are similar can be generally defined as the San Joaquin Valley, Sacramento Valley, and Coastal areas.

The Kern District is the most southerly of the mosquito abatement agencies in the San Joaquin Valley. Districts in this region have more closely paralleled the pattern experienced by Kern than have control agencies in the other two regions. Some of them have encountered resistance to DDT and other chlorinated hydrocarbons; although, at the northern end of the San Joaquin Valley, adequate tests have not been conducted to determine the degree of resistance to the chlorinates. It is interesting to note, however, that where initially they used DDT at a rate of approximately .25 lbs. per acre, it is now common practice to use 1 lb. to the acre.

This region also boasts the dubious distinction of having a number of districts substituting phosphates for the chlorinates in their control programs. Of 15 districts in the region, 13 are using some phosphate larvicides; and of these, 6 are using them almost exclusively. Four districts use parathion by both ground and airplane equipment, where 3 use it in planes with either EPN or malathion applied with ground equipment. There are 4 districts who have used only malathion of the phosphate group and then usually only to supplement their chlorinate materials.

Immediately north of the San Joaquin is the Sacramento Valley region. Here, there seems to be no confirmed evidence by adequate testing of resistance to DDT or other chlorinates; although some agencies are reporting a very high resistance to DDT where formerly they obtained good results with about .25 lbs. to the acre. Some malathion was used in this region during the past season.

In the coastal region there seems to be little, if any, evidence of resistance to DDT or other chlorinates, which are used in both aqueous emulsions and oil solutions. Rates of application may have been increased somewhat during the past few years and are ranging generally from .5 lb. to 2.0 lbs. per acre on salt marshes in order to meet the wide variances in alkalinity and dissolved substances occurring in such water sources. Some phosphate is being used in this region, primarily malathion.

In the light of experiences of the past 2 or 3 years, it seems evident that phosphates are succeeding chlorinates for mosquito larviciding purposes, particularly in the San Joaquin Valley. This is apparently the result of mosquitoes, especially *Culex tarsalis,* developing resistance to various chlorinates where they have been continuously used for periods from 3 to 6 years. During the past season four districts used parathion by ground and aerial application, while an additional 3 used it by plane along with either malathion or EPN for ground application. No accidents or ill effects were noted, even though parathion, in particular, is extremely toxic to mammals by acute poisoning. It seems, therefore, that if all personnel handling this material are properly instructed in its use and maximum protection is provided them, it can be used without too great a hazard, and more economically than some of the chlorinates.

As to the problem of chronic toxicity, many phosphates have an advantage of limited or no residue problem as compared to most of the chlorinates. As a matter of fact, if they can be safely handled by the operators when used as a mosquito larvicide, the phosphates should possibly have preference over the chlorinates because of the residual properties of the latter.

Tolerances for Pesticide Residues proposed by the U.S. Department of Health, Education and Welfare, Food and Drug Administration in the Federal Register for October 20, 1954 are:

0 (no residue permitted) for calcium cyanide, DNOSBP, DNOC, TEPP, HCN, mercury, nicotine, and selenium

0.1 ppm for aldrin, chlordane, dieldrin, and heptachlor

1 ppm for combined lead in lead arsenate on citrus, DN-111, naphthalene, ascetic acid, and parathion

3 ppm for EPN

3.5 ppm for combined arsenic trioxide in arsenicals and combined antimony trioxide in tartar emetic

5 ppm for BHC, 2,4-D, and 2-heptadecyl glyoxalidine

7 ppm for DDT, ferbam, combined fluorine, combined lead arsenate (other than on citrus), phenothiazine, TDE, toxaphene, zineb, and ziram

10 ppm for lindane

14 ppm for methoxychlor

These are not blanket tolerances, but apply only to specific fruits and vegetables listed in the proposed regulations. Yet, replicated heavy dosages of long residue chlorinates when applied for mosquito larviciding purposes certainly afford a potential toxicological hazard.

In respect to this problem, I quote Dr. A. J. Lehman, Chief, Division Food & Drug, Washington, D.C., from his report, "Conservatism in Estimating the Hazards of Pesticidal Residues."

"The allusion to fatal or non-fatal illnesses attributed to insecticides carries with it the implication of an acute exposure to pesticidal chemicals. This can occur in people who apply the new pesticides. The hazards involved are pretty obvious and can be corrected. It is more difficult to evaluate the more subtle effects of these chemicals, and the ground for uneasiness rests in the fact that some of the newer insecticides are introduced into commercial practice before sufficient pharmacological studies have been carried out for an adequate evaluation of the chronic effects. Even when the chronic effects are fairly well understood, the problem of more extensive use of a particular pesticide, new uses, or its carryover into other food products as an unintentional additive is always cause for concern.

"Pesticides creating this disquieting situation are those that are persistent and likely to leave significant residues and whose chemical nature is such that they or a toxic metabolite or both are stored in the body. DDT is a good example to illustrate this. In our work on DDT we have found that when rats are fed the insecticide at a level of 5 parts per million in the total diet for several months, definite though minimal liver damage can be demonstrated in these animals.

"If agricultural crops were the only source of DDT residues, we could readily subscribe to the reasonableness of the belief that there is no evidence of danger arising from the eating of foods treated with crop-protecting chemicals. By the same token, we could not subscribe to the unsound opinion that the public is being subjected to mass poisoning. However, as new uses for DDT have developed, the possible amount capable of being ingested is increased. The use of DDT in dairy barns and its appearance in the milk, applications in food-processing plants where contamination may result, and as a treatment for food-packaging materials to prevent invasion of the finished product by insects, all could be additional sources of contamination. Under these conditions a presently minimal exposure could materialize into a serious situation and the need for caution is ever-present.

"In this connection, it may be mentioned that the Food and Drug Administration recently made a survey in which 75 samples of human fat were analyzed for DDT. DDT or a metabolite was found in all but 15 samples, the average being 5 ppm, but in 9 samples the concentration ranged between 10 and 20 ppm.

"All but 2 of 32 samples of human milk also revealed the presence of DDT, the average concentration being

0.13 ppm. It may be added that none of the subjects was occupationally exposed to DDT; therefore, we can assume that contact with this insecticide came through the food or possibly through the occasional spraying done in the house or garden.

"It has been our general philosophy that whenever evidence comes to light indicating that a compound, its degradation product, or its metabolite is stored in body tissue, the compound becomes surrounded with an element of doubt regarding its toxicity, especially on the basis of long-term exposure. We have long stressed the importance of the fact that storage and ability to injure tissues go hand in hand. DDT, for example, is stored in the fatty tissues of the rat, the animal most extensively studied, at the rate of 6 to 14 times the intake in the range of 5 to 10 ppm in the diet. As already stated, definite though minimal liver damage is noted at 5 ppm. When rats are fed chlordane at 2½ ppm, chlordane or a chlordane-like substance attains a level in the fat of about 36 times the intake. The level of feeding which will produce minimal liver damage has not been as precisely determined for chlordane as for DDT, but it is some value around 2½ ppm. Methoxychlor, on the other hand, is not stored under normal conditions and the level of feeding must reach 200 ppm or more before any injurious effect can be noted in the animals.

"Not only must storage be considered, but the degradation product or metabolite and its behavior must be taken into account also. At one time it was generally believed that whenever a toxic substance was absorbed, the body was capable of calling upon special mechanisms for detoxifying the toxicant. It was believed also that the metabolic pathway that the toxicant followed always proceeded in the direction of the formation of a less toxic compound. Later work on the metabolism of drugs and toxic substances showed that special mechanisms did not exist, but that the toxicant was subject to the same metabolic influences as those which normally operate in the body. The assumption that the metabolic product was less poisonous than the parent substance from which it was derived also is unwarranted, simply because in many instances the toxicity of either the original substance and its conversion product is unknown. In other instances, the metabolic product is even more poisonous than its parent. The conversion product, heptachloroperoxide, which is two or three times more poisonous than the parent substance, heptachlor, may be cited as an example of this.

"Let us again consider DDT in light of these facts. A recent report shows that the material stored after the ingestion of DDT is not all DDT but is in part DDE, dichloro-diphenyl-dichloroethylene. The report tends to minimize the importance of the storage phenomenon, since DDE is somewhat less toxic than DDT. A still more recent experiment on DDT-resistant flies shows that the presence of DDE in the body increases the toxicity of DDT by slowing down its metabolism. This is by the 'law of mass action': when the end products of a reaction pile up, the reaction slows down. Similar experiments have not yet been performed on warm-blooded animals, but the above observations cast doubt on the inferred harmlessness of DDE stored in animal fat.

"In summary, it is not a 'fact' that the small amounts of insecticidal residues man now ingests are harmless; there are no unimpeachable data that can prove this even beyond a reasonable doubt. Facts about acute toxicity do not apply to the argument at all. Conservatism, to serve as a brake for indiscriminate use of insecticides, should govern all actions at the present time. In taking a conservative attitude there is no necessity to restrict the use of insecticides below limits where they would serve a useful purpose. But the attitude should be strictly maintained that a relaxation of controls is not justified on the basis of present scientific knowledge."

A SUMMARY OF HUMAN EXPOSURES TO MALATHION AND CHLORTHION DURING AEROSOLING OPERATIONS

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This is the summary of a companion study to that by C. M. Gjullin and Richard F. Peters reported under the title, "The Effectiveness of Some Organic Phosphorus and Other Insecticides as Aerosols Against Mosquitoes." The above study provided us with the race opportunity to investigate human exposure to two recently developed organic phosphorus containing insecticides, since in the performance of their work the entomologist would be exposed to these materials.

In studying human exposure we had five main objectives:

1. To insure that no serious toxic effects of exposure to malathion and chlorthion would occur to men during their field study of the mosquiticidal properties of these two relatively new organic phosphate insecticides.
2. To obtain an estimate of human toxicity of malathion and chlorthion.
3. To obtain a measure of air concentrations of an insecticide aerosol at various distances from the source, correlative with the equipment used.
4. To study the magnitudes of exposure to different parts of the body.
5. To obtain, if possible, an estimate of the risk to humans employed regularly in mosquito control while using these materials.

MATERIALS AND METHODS

To achieve the objectives of this phase of the study, a medical environmental team was assembled, consisting of industrial hygiene engineers, analytical chemists, physicians, clinical laboratory technicians, and nurses.

Air sampling at the breathing zone of the members of the entomological team was done by the engineers, using glass midget impingers to estimate inspiratory exposure. Absorbent cellulose pads were placed on various parts of the bodies of the entomologists and a cotton glove was used on one hand to measure skin exposure of these men. The results of these two techniques were used to give a measure of exposure for each member of the entomological team.

Chemical analyses of malathion samples were performed according to methods developed by the American Cyanamid Company, chlorthion samples by a modification of the Averell Norris method. All patches were analyzed by the total phosphorus method.

Blood cholinesterase determinations and physical examinations were done daily during the periods of exposure. Arrangements were made for complete emergency medical care in case of accidental poisoning.

MEDICAL DATA

Twenty-three aerosoling runs were made with malathion during a period of two weeks. Fourteen aerosoling runs were made with chlorthion during the succeeding week.

During these runs one man, J. K., weight 65 kilograms, drove the jeep carrying the Husman generator and/or towing the Beskil generator. This man also did much of the formulating and filling of the tanks of the generators.

C. G., weight 75 kilograms, assisted in formulating and directed application by walking behind or on the windward side of the jeep during both the malathion and chlorthion applications.

W. J., weight 78 kilograms, made pre-application mosquito counts in the field to be aerosoled, then was stationed 10 yards downwind from the line of application during the passage of the aerosol cloud to observe immediate effects of the insecticides on the adult mosquitoes. At varying time intervals he then made mosquito recounts of the fields treated. He was exposed to malathion only.

J. L., weight 79 kilograms, did work identical to that of W. J. except that he was stationed at 17 yards from the line of application during the aerosoling operation and was exposed to malathion and chlorthion. During the chlorthion exposures his station was 10 yards from the line of application.

B. M., weight 64 kilograms, was similarly occupied but was stationed at 25 yards and was exposed only to malathion.

G. C., weight 84 kilograms, was exposed only to chlorthion and during actual aerosoling operations was stationed 17 yards from the source.

E. M., weight 74 kilograms, was exposed only to chlorthion and was stationed 25 yards from the source.

During all periods of exposure the men were well clothed, wearing hats, long khaki trousers and long-sleeved shirts with cuffs buttoned around the wrists and collars buttoned at the throat. Occasionally neckerchiefs were also worn.

Exposure periods were brief, ranging approximately from 30 seconds to 25 minutes. They were distributed rather evenly throughout the spans of time devoted to each insecticide. The sum of these periods for each man is presented in Table 1.

Table 1 also gives figures for estimated total amounts of malathion and chlorthion deposited on the exposed skin of these men and inspired through their nostrils. Figures for amounts inspired through nostrils are subject to considerable question on the basis of certain theoretic considerations. These theoretic considerations are being investigated in several laboratories at the present time.

Some exposures are reported as ranges, because occasional single unmeasured exposures were estimated by taking from similar exposures which were measured a mean figure plus and minus one standard deviation.

In answer to our first objective, the welfare of the men during the exposure periods for malathion and chlorthion, none of the clinical laboratory determinations or observations obtained by physical examination varied outside generally accepted normal limits. In short, there was no indication that any of the men showed any physiological or pathological variations ascribable to a cholinergic material.

With regard to our second objective, we have not a measure of human toxicity, but rather a measure of a level of exposure that did not cause clinical human intoxication.

Attempts to gain our third objective, the measurement of air concentration, resulted in a few tentative conclusions. Windborne aerosol clouds generated in the field have no uniform concentrations, thus presenting a difficult sampling problem. For this reason, air sampling with the midget impinger at 10, 17, 25, 50, and 75 yards was started prior to the arrival of the aerosol cloud and continued for a period of time following visual evidence that the moving aerosol cloud had passed by. Since sampling was done from stationary points, the curve in the following graph plotting the average number of micrograms in the impinger samples against distance from the source of the aerosol illustrates an important concept. It may be seen that between 10 and 75 yards amounts ranging from 21.5 micrograms to 13 micrograms were found. From this we may conclude that very similar amounts of material in a windborne aerosol cloud pass by a stationary point without regard to variations in concentration, time, or distance from source. Within what limits this concept may be true is as yet unknown.

It was found that there was no significant variation in amounts collected by the air sampling device correlative with times when concentration of the formulation or application rate were increased by as much as fourfold. The explanation for this may be that variations in micrometeorological conditions were of a greater order of magnitude than those of insecticide application and thus obscured the effects of the latter.

In order to compare our impinger sampling with those of other studies, the engineers, with the aid of stop watches, recorded their estimates of the duration of cloud exposures. From these figures we have calculated air concentrations. These are reported in Table I, but must be considered only very rough approximations.

The results relating to our fourth objective, that of

TABLE I

MERCED INSECTICIDE STUDY 1954

Malathion Exposure Data

Operators	Total skin expos. Mg.	Total insp. expos. Mg.	Sum of expos. periods during 23 spray runs Hrs.	Av. air conc. Mg/m^3	Highest air conc. Mg/m^3
J. K.	32-86	11-21	5.23	2-4	56
C. G.	6-14	9-12	5.07	2-3	56
W. J. (10 yds.)	7-13	2-5	4.23	.5-1	51
J. L. (17 yds.)	7-14	1-2	3.91	.5	8
B. M. (25 yds.)	7-10	2	4.87	.5	11

Chlorthion Exposure Data

Operators	Total skin expos. Mg.	Total insp. expos. Mg.	Sum of expos. periods during 14 spray runs Hrs.	Av. air conc. Mg/m^3	Highest air conc. Mg/m^3
J. K.	9-15	3	2.58	1.5	11
C. G.	1-5	5	2.12	2.6	27
J. L. (10 yds.)	2	2-3	4.31	.6-.7	12
G. C. (17 yds.)	1	2-3	4.08	.6-.8	20
E. M. (25 yds)	1	2-4	3.98	.8-1.3	14

exposure to the various body areas, are summarized in Table II. It will be noted that by far the largest skin exposure was upon the hands of the jeep driver and probably resulted from formulating and transferring formulated insecticide from a five gallon can to the Husman tank. The total skin exposure for this man was in the range 32 to 86 milligrams and 27 to 80 milligrams were found on the hands. The hand exposure was incurred even though the man worn long rubber gauntlets during all periods of exposure. It was probable that the technique used in putting on and taking off these gloves was inadequate to avoid gross skin exposure. This emphasizes a point made by others in the past, namely, that considerable skill must be exercised in the use of protective devices so that they do not become a major source of contamination.

Inspiratory exposure was much larger compared to skin exposure than we had anticipated. Table I suggests that occasionally inspiratory exposure may be two to three times larger than skin exposure. This was probably due to the smallness of droplet size in the aerosol since, theoretically, the smaller the mean diameter of particles dispersed in air, the greater will be the relative inspiratory exposure. Conversely in sprays where droplet size is large, the inspiratory exposure may be slight compared with skin exposure.

DISCUSSION

It might be of interest to compare amount of malathion

TABLE II
MERCED INSECTICIDE STUDY 1954
Malathion per Exposure Areas
Amounts in Milligrams

Operators	*Hand*	*Legs*	*Face*	*Total skin expos.*	*Total insp. expos*
J.K.	27-80	..*	4-6	32-86	11-21
C.G.	3-10	..*	2-3	6-14	9-12
Field Observers					
W.J. (10 yds.)	2-6	1-3	4-	7-13	2-5
J.L. (17 yds.)	2-5	1-2	5-7	7-14	1-2
B.M. (25 yds.)	2-3	2-3	3-4	7-10	2-

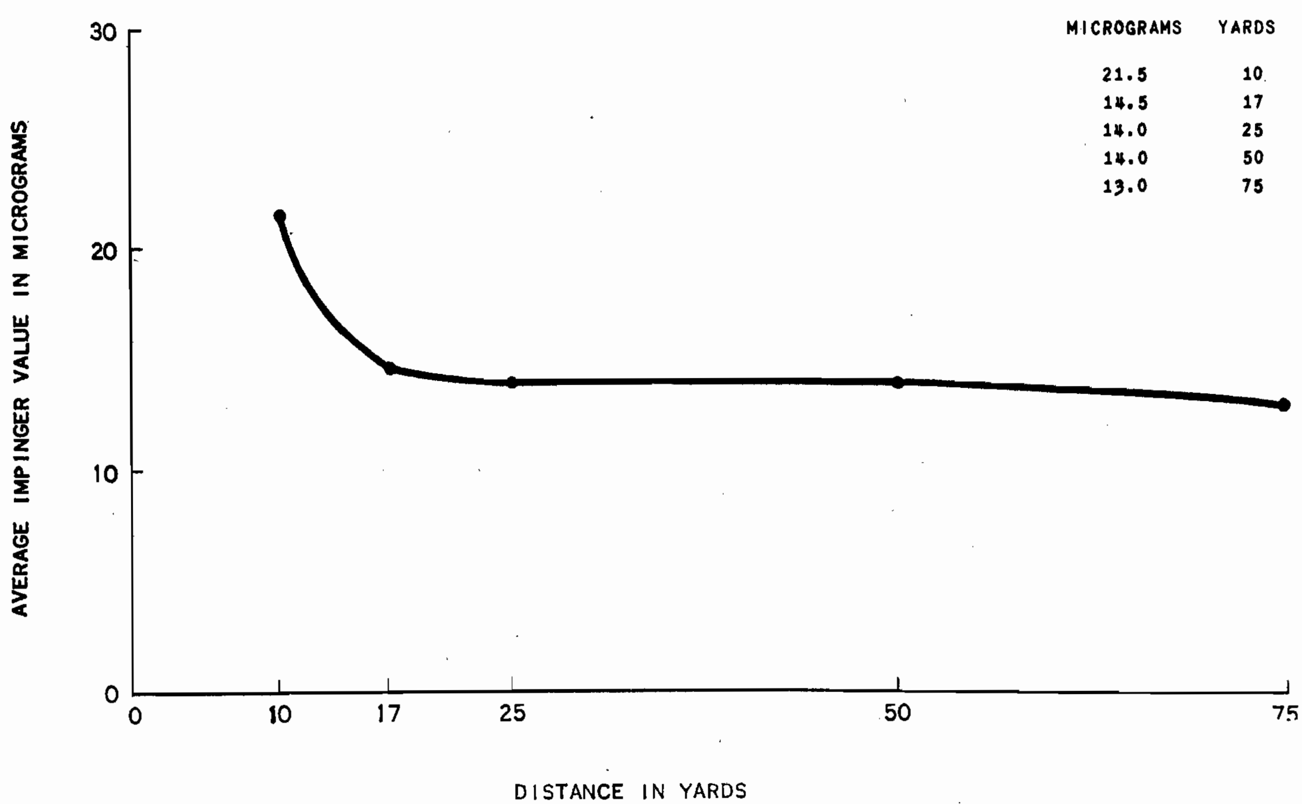
Clorthion per Exposure Areas
Amounts in Milligrams

Operators	*Hand*	*Legs*	*Face*	*expos. Total skin*	*expos. Total insp.*
J.K.	9-14	..*	1	9-15	3
C.J.	1-4	..	..	1-5	5
Field Observers					
J.L. (10 yds.)	1	..	1	2	2-3
G.C. (17 yds.)	1	..	..	1	2-3
E.M. (25 yds.)	1	..	1	1	2-4

*—Indicates amounts below 0.5 mg.

MERCED INSECTICIDE STUDY, 1954

AVERAGE AMOUNTS OF MALATHION AT VARYING DISTANCES FROM SOURCE OF AEROSOL



and chlorthion received by the men engaged in this study with amounts used in animal experimentation and figures proposed as threshold limits for man. For malathion, J. K. received a skin exposure in the range of 0.5 to 1.3 mg/kg acquired in short intervals during the two week exposure. This may be compared with the acute dermal LD_{50} for guinea pigs in excess of 12,300 mg/kg. The threshold limit for air concentration proposed by the American Conference of Governmental Industrial Hygienists is 15 mg/M^3. This is the greatest amount considered safe for a man to be exposed to for 8 hours per day five days per week, and may be compared with the average level of air exposure of J. K. estimated to be in the range of 2.4 to 4.2 mg/M^3 and to his highest exposure 55.7 mg/M^3.

From the small amount of literature available on animal work with chlorthion, it appears that the toxicity for chlorthion is of the same order of magnitude as that for malathion. The greatest skin exposure was that of J. K. and was in the range of 0.14 to 0.23 mg/kg acquired over a one-week period. C. G. was exposed to the highest average air concentration of chlorthion. This was estimated to be approximately 2.6 mg/M^3. The highest concentration to which he was estimated to have been exposed was 26.6 mg/M^3.

Our highest figures for exposed and unexposed skin areas suggest that a person dressed in long trousers and a short sleeved sport shirt, standing during a single cloud passage ten yards from the line of traverse of a Beskil or Husman generator dispersing malathion or chlorthion at rates used in this study would receive less than 1.8 milligrams of insecticide on his skin and inspire less than 0.7 milligrams of insecticide. These amounts are so far below levels calculated to be in the range of toxicity as to be negligible.

To answer our fifth objective, that of safety for operators in a mosquito control program, we may base calculations on exposure data of J. K., driver and person who handled most of the formulation, and who had the largest exposure. Projected to a 40 hour week basis and assuming casual clothing changed frequently enough to avoid saturation, he would have acquired a skin exposure of less than 125 mg/kg during on month of work. This is less than one one-hundredth of an acute LD_{50} for guinea pigs. The average air concentration to which he was exposed was in the range of 2.4 to 4.2 mg/M^3. This is less than one-third of the threshold limit proposed by the American Conference of Governmental Industrial Hygienists. Thus it appears that there would be no great hazard from malathion and chlorthion to operators using reasonable precautions while aerosoling adult mosquitoes.

SUMMARY

A group of seven entomologists received exposures to malathion and chlorthion during an insecticide study. The magnitude of these exposures were measured by industrial hygiene techniques and by methods developed by the U. S. Public Health Service. Clinical laboratory tests and frequent physical examinations indicated that the entomologists were unaffected by these cholinergic materials. Magnitudes of exposure were compared with results from animal experimentation. From calculations of exposures which might be acquired during work on a 40 hour week basis, we estimate that these materials could be used without great hazard to operators aerosoling adult mosquitoes.

ACKNOWLEDGEMENTS

The medical environmental phase of this study was made possible by the invaluable assistance of the Wenatchee Field Station personnel, U. S. Public Health Service; Dr. H. H. Golz, Miss Florence Hermenze, and Mr. Brennan Gisclard of the American Cyanamid Company; Dr. Frank Brewer and his staff of California's Merced County Health Department; personnel of the Merced County Mosquito Abatement District; members of the State Health Department's Industrial Hygiene Laboratory, and last but not least, Mr. James Lanier, entomologist from the Chemagro Corporation and entomologists of the State Health Department's Bureau of Vector Control and the U. S. Department of Agriculture who willingly submitted to all requests for blood samples and to discomforts of endless physical examinations.

FIFTH SESSION (Concurrent)

9:30 A.M., WEDNESDAY, JANUARY 26, 1955

ST. LOUIS ROOM, HOTEL STATLER

This session for the presentation of submitted papers was presided over by Donald L. Collins, New York State Science Service, Albany, New York. The addresses given by Osmond P. Breland, Department of Zoology, University of Texas, on "Variations in the Larvae of *Culex stigmatosoma* from Texas" and by Dr. John N. Belkin and William A. McDonald, Department of Entomology, University of California at Los Angeles, on "Isolated Populations of Mosquitoes in Death Valley," were not submitted for publication.

CULEX TARSALIS AND THE GRASSLAND BIOME

William F. Rapp, Jr.
Division of Sanitation, State Department of Health, Lincoln, Nebraska

In the spring of 1952, there was a serious flood in the Missouri River Valley of Iowa and Nebraska. As a result of this flood, there were numerous ponds and puddles left on both the upper and lower flood plain. With this large area of water for mosquito breeding, it was decided to run New Jersey Mosquito Light Traps throughout this area. One of the interesting results of this work was the fact that *Culex tarsalis* seemed to be a rare mosquito in the Missouri River Valley. At the same time the light traps were being run in the Missouri River Valley, a trap was run at the author's home at Crete, Nebraska. At Crete, *Culex tarsalis* proved to be the number two mosquito, being exceeded only by *Aedes vexans*. The results from Missouri Valley were contrary to the existing thought on this mosquito, heretofor, that *Culex tarsalis* was considered common throughout the state. As a result of this work, it was decided to determine the variation in population of *Culex tarsalis* in various parts of Nebraska. An examination of the work done by Tate and Gates showed that as one progressed west across the state, the *Culex tarsalis* population increased in a direct proportion; the panhandle having the highest average per trap night. Actually, the largest number were taken at Whitney, Nebraska, where in 50 nights, 14,152 specimens of *Culex tarsalis* were taken in the summer of 1942. This represents

283 per trap night. Thus it was evident that as one went from tall grass prairie, through mixed prairie to the short grass prairie, there was a marked increased in *Culex tarsalis* population.

With this in mind, it was decided to see if this was purely a phenomenon limited to Nebraska or if it existed throughout the grassland area. The only work that was comparable to the work of Tate and Gates was the work done by Dr. John Roe in Iowa, published in 1942. Again Roe's work showed a low population in the Mississippi River Valley and increased as one went westward across the state and then a decrease in the Missouri River Valley. It was decided to graph this data, and the results are seen on the slide. The states of Iowa and Nebraska were divided into areas of similar ecological conditions, and the light trap data averaged and then plotted.

One finds a curve which is roughly increasing in population as one moves westward. The closer examination of this curve indicates that in the Mississippi River area of Iowa there is a low mosquito *(Culex tarsalis)* population; but as one progresses to Central Iowa there is a marked increase in the population of the species. Then when the Missouri River Valley area is reached, there is again a decrease back to a population density approximately the same as found in the Mississippi River Basin. This decrease in population may be attributed to the fact that these river valleys are typical deciduous forest areas rather than grassland areas; and, since *Culex tarsalis* is a grassland species, it does not thrive well under forest conditions. From the ecological point of view, there is a very little difference in these two river valleys. They are principally oak, hickory, cottonwood, and walnut woodlands along these rivers, and are considered by ecologists to be westward extensions of the deciduous forests of eastern North America. Another close look at the graph shows that from thereon, there is a steady rise until one reaches the western portion, or Nebraska, where there is also a slight decrease in population, thus making an irregular jag in the curve. The only explanation available for this slight drop in mosquito population stems from the fact that there was not a large number of traps run in this area plus the fact that traps may not have been placed in situations which would attract the maximum number of mosquitoes. When one reaches the western portion of the State, there is a very significant rise in *Culex tarsalis* population. It is extremely unfortunate that there is no data available for the State of Wyoming, so that we could see whether the population still increases as you go westward toward the mountains. The law of least squares was applied to the data used in compiling the curve; the straight line curve for the data was determined and will be observed as a straight line of positive accent. This straight line which was determined by use of the law of least squares definitely shows the trend of *Culex tarsalis* population as one works westward through the prairie areas.

Also plotted is the rainfall for the same areas in which the light traps were run. This data was compiled from information found in the year book of Agriculture entitled "Climate and Man." The popular opinion has always been that there is a positive correlation between mosquito population and annual rainfall; however, in the case of *Culex tarsalis,* as the rainfall decreases, the population increases; thus, we have an exception to the oft stated rule that the higher the rainfall the higher the mosquito population.

A study of *Culex tarsalis* populations as determined by light traps indicates that as one progresses westward the mosquito population increases as you travel from the tall grass prairies of Iowa and eastern Nebraska to the short grass prairies of western Nebraska. There is a marked decrease in the *Culex tarsalis* population in the deciduous forest river valleys found in the Valley of the Mississippi and the Missouri. Also, it has been shown that the annual rainfall decreases as the *Culex tarsalis* popula-across the grasslands of North America, one finds that tion increases.

THE PROBABLE CORRELATION BETWEEN INCREASING SALINITY AND THE DISAPPEARANCE OF THE GNAT, *TENDIPES DECORUS* (JOH.), FROM MORICHES BAY

HUGO JAMNBACK AND D. L. COLLINS
New York State Science Service

The "Mroiches Bay Fuzzbill," *Tendipes decorus* (Joh.), a non-biting gnat, was very abundant and annoying around water-front property on Long Island, New York, in 1952 and 1953, particularly in Mastic Beach, the Moriches, Speonk, Remsenburg, and Westhampton Beach. It became such a nuisance that a study of the possibility of controlling it was undertaken in 1953 by the New York State Science Service and the Suffolk County Mosquito Control Commission. Larval breeding was found to be largely confined to Moriches Bay and its tidal creeks, an area of about 13,000 acres. In 1953, Moriches Bay was connected only indirectly with the ocean by narrow channels. Numerous fresh water creeks and springs flow into Moriches Bay. As a consequence the water in the bay was much less salty than that of the ocean. Specific gravity readings taken in the bay proper ranged from 1.006 to 1.011 and from 1.000 to 1.006 in the tidal creeks while that of th ocean was about 1.024.

Since work on a direct opening from the ocean into the bay was under way, studies of the effects of the increasing salinity, approaching that of the ocean, were made to determine whether or not larval breeding would be inhibited. Both laboratory experiments and field observations indicated that larvae were adversely affected by high salinity. Methods used in the studies and information obtained are given in more detail in "The biology and control of the midge *Tendipes decorus* (Joh.) in Moriches Bay," Report of Investigation No. 6, New York State Science Service, Albany, N.Y. These studies indicated that an inlet from the ocean into Moriches Bay would probably restrict larval breeding to the portions of the tidal creeks where the salinity remained relatively low and might reduce breeding to a point where the fuzzbills would no longer be a problem.

Table 1. Correlation between increases in salinity and disappearance of *T. decorus* larvae in Moriches Bay.

Months after inlet was opened	Highest specific gravity values*	No. of samples	Larval Abundance % of samples with indicated nos. of larvae	
			0-9	10-100x
(Before)	1.011	189	54.5	45.5
1	1.021	39	71.8	28.2
5½	1.024	22	90.9	9.1
11	1.024	47	100.0	0.0

*Specific gravity is taken as the index of salinity.

Three surveys were made after the inlet was opened on September 18, 1953. Table 1 shows the progressive decrease in larval populations correlated with the increasing specific gravity of the water in Moriches Bay after the inlet was opened.

In the last survey, made in August, 1954, eleven months after the inlet was opened, no larvae were found either in the bay proper or in the tidal creeks. The total absence of larvae from the creeks is surprising because, in some parts of the creeks, the specific gravity readings were less than 1.011, the highest concentration in which larvae were found breeding in large numbers in 1953. The lack of larvae in the tidal creeks may be due to storms which increased the salinity in the creeks long enough to inhibit larval breeding. Another factor which may be of significance is the reduction in amounts of nitrogen and phosphorus compounds in the water. These compounds were present in high concentrations before the inlet was opened due to the extensive duck breeding and limited exchange of water (Redfield, 1952). The effects of the hurricanes of August 31 and September 11, 1954, have not been ascertained. If the inlet is closed, or its flow is greatly diminished, the midges may again become a serious problem in two or three years.

REFERENCES CITED

Redfield, A. C.
1952. Report to the Towns of Brookhaven and Islip, N.Y., on the Hydrography of Great South Bay and Moriches Bay. Woods Hole Oceanographic Institution Ref. No. 52-26; 1-80.

PROGRESS IN A STUDY OF THE MOSQUITOES OF THAILAND*

WILLIAM E. BICKLEY
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ABSTRACT

Last year at the meetings in Atlantic City Ernestine B. Thurman gave a report on the establishment of a Malaria Control Training Center in Chiengmai, Thailand, and reviewed briefly some of the accomplishments of the late Deed C. Thurman, Jr. and herself while they were assigned to the U.S. Operations Mission to Thailand, Foreign Operations Administration. After her return to the United States in 1953, Mrs. Thurman continued her study of Thai mosquitoes under FOA sponsorship at the U.S. National Museum in Washington. The Thurman collections brought from Thailand contained approximately 100,000 specimens, most of which were accessioned by the National Museum. The assistance of Dr. Alan Stone has been invaluable. At the beginning of the taxonomic study it was found that because of the abundance of material to be studied and the discovery of many forms that are believed to be undescribed species, several years' work would be involved.

In September, 1954, the work was accelerated largely because of support furnished by the Division of Research Grants, National Institutes of Health, Public Health Service, U.S. Department of Health, Education, and Welfare. A grant administered by the University of Maryland has made possible technical and clerical assistance; laboratory and office facilities of the Department of Entomology are provided for the execution of the project. The project is entitled "Biology and Taxonomy of Mosquito Vectors and Potential Vectors in Thailand." The principal overall objective is to make available to military and civilian agencies information that will be useful in the control of mosquito-borne diseases.

A major consideration in carrying out the project is the preparatorial work. The handling of so many specimens is a laborious task. A large proportion of the adults has been mounted on points, and the preparation of male terminalia and immature forms on slides is proceeding at a rapid rate. Even a detail such as writing labels becomes extremely time consuming. To expedite the preparatorial work, punch cards are used for sorting and analyzing collection data.

Recently Mrs. Thurman has completed keys to all genera of adults and larvae and species keys for *Anopheles* adults and larvae. These have been mimeographed and sent to Thailand for immediate use and for possible modification prior to publication. Species keys for identification of adults and larvae of *Aedes, Armigeres, Mansonia,* and *Culex* will be completed in the near future. An annotated list is in final stages of preparation.

It is expected that the work of Dr. and Mrs. Thurman will be integrated with studies which Dr. Melvin E. Griffith is continuing in Thailand. The ultimate goal is a monographic treatment of the Thai mosquitoes. It is believed that new distribution records of approximately 50 species and descriptions of approximately 30 new species will be reported. Additions to the knowledge of the Thai fauna, among other things, should assist in controlling malaria, filariasis, dengue, encephalitis, and other mosquito-borne diseases.

*Miscellaneous publication No. 222. Contribution No. 2590 of the Maryland Agricultural Experiment Station, Department of Entomology.

SIXTH SESSION (Concurrent)

1:30 P.M., WEDNESDAY, JANUARY 26, 1955

SIERRA ROOM, HOTEL STATLER

Dr. Stanley B. Freeborn, University of California at Davis, presided over this session on "Mosquito Ecology" and gave introductory remarks which were withheld from publication.

THE ROLE OF VECTOR ECOLOGY IN THE EPIDEMIOLOGY OF MOSQUITO-BORNE DISEASES

(Some general considerations with examples from Malaria, Yellow Fever, Filariasis, and the Arthropod-borne Encephalitides)[1]

R. EDWARD BELLAMY, *Scientist*

The following two questions largely paraphrase the title: (1) How is it that some species of mosquitoes serve as efficient vectors of certain diseases while other mosquito species fail to do so? (2) What relationships exist between the mosquito vector and its environment that limit or promote the efficiency of the disease transmission phenomena? An attempt will be made to supply some answers to these questions through examples of vector relationships of several selected mosquito-borne diseases of man, with only passing reference to diseases transmitted by mosquitoes to other vertebrate animals but not to man.

Epochal discoveries by Manson, Ross, and others late in the nineteenth century showed that mosquitoes as well as man serve as host to filarial worms and the protozoan parasites of malaria. At the turn of the century, Walter Reed and his associates demonstrated that *Aedes aegypti* (L.) transmitted yellow fever, and that the disease was produced by a filterable agent. In the half century since these discoveries, blood-sucking arthropods, and mosquitoes in particular, have been incriminated as vectors of a host of parasitic diseases of man and other vertebrates. Marston Bates (1949) pointed out that with only a few obscure exceptions the vertebrate diseases known to be transmitted by mosquitoes are caused by organisms of four major groups: viruses, haemosporidia, filarial worms, and botflies of the genus *Dermatobia*.

For a mosquito to serve as the vector of a vertebrate parasite, it must fulfill certain general requirements. It is obvious, for instance, that the mosquito must occur at the same time and place as the disease-producing organism. The mosquito must obtain the organism; ordinarily this is through the blood-feeding habit of the adult female (exception: transmission of *Dermatobia hominis*). Also, the mosquito must convey (or transmit) the infectious organism to a susceptible host. To accomplish this the infected mosquito must bite again. As obviously important as this requirement is, it has received too little attention in studies of mosquitoes in relation to disease. It is also generally true that a primary vector species must be sufficiently numerous that the likelihood of transmission will not be remote. Finally, the body of the mosquito must provide an adequate physiological environment for the survival and any necessary development of the parasite. In this connection it is appropriate to refer to Huff's (1931) four classes of relationships of vertebrate parasites to their arthropod vectors. These (cyclopropagative, cyclodevelopmental, propagative, and mechanical) are based on whether or not metamorphosis or multiplication, or both, occur in the arthropod.

In addition to the requirements of more or less general application to all vector relationships, there are numerous special requirements which vary with (1) the parasitic organism, and (2) the precise physical and biotic environment at the different localities where these various parasitic infections persist or recur. To illustrate such vector relationships, examples have been chosen from the massive accumulated lore on several of the more serious, and therefore more studied, mosquito-borne diseases.

MALARIA. Malaria is (or recently has been) widespread throughout the temperate and tropical regions. Only anopheline mosquitoes are known to transmit human malaria, but representative species of this group are found on all continents and in some island archipelagoes. New Zealand and an area of the South Pacific constitute an exception, and apparently malaria transmission does not occur there. In the Holarctic region several members of the *Anopheles maculipennis* complex (in a broad sense) are important malaria vectors. For example, malaria is transmitted by *A. sacharovi, A. labranchiae,* and *A. atroparvus* in Eurasia, the middle East, and the Mediterranean area; by *A. quadrimaculatus* in eastern North America; and by *A. freeborni* in California. Many important vectors in the subgenus *Myzomyia* occur in tropical Africa, the Mediterranean area, India, Malaysia, and the Far East. (A few examples are *A. gambiae, A. funestus, A. sergenti, A. superpictus, A. culicifacies, A. sundaicus, A. minimus* subssp., etc.). In South and Central America and the Caribbean area, most of the important vectors are members of the subgenus *Nyssorhynchus* (examples: *A. albimanus, A. aquasalis,* and *A. darlingi*); but *A. pseudopunctipennis* and *A. bellator* are important in certain portions of their ranges.

The "good" natural vectors of human malaria are species of *Anopheles* which feed on man readily, just as in bird malaria the principal vectors are aviophylic species of *Culex*. In the eastern United States *A. quadrimaculatus* not only bites man but frequently invades houses. In the same region, *A. punctipennis* and *A. crucians* feed primarily on the blood of large domestic mammals. In the past, malaria occurred where there were large populations of *A. quadrimaculatus* but was absent from localities where only *A. crucians* or *A. punctipennis* were numerous. This is similar to the situation in Europe where the different members of the *maculipennis* complex had different feeding habits, with those which seldom bit man playing little or no part in malaria transmission (Hackett, 1937). Also, in California, *A. freeborni* bites man readily and often enters houses. This species was accordingly associated with malaria, while *A. occidentalis, A. franciscanus,* and *A. punctipennis* seldom enter houses in California and apparently were innocuous.

Malaria is usually acquired at night since most vector *Anopheles* are nocturnal or crepuscular feeders. A few species of *Anopheles* bite fiercely in daylight, but such species (example: *A. walkeri*) are usually wild forms which remain in marshes or forests close to their breeding areas and do not function as important vectors.

In temperate climates malaria transmission normally occurs in the summer, but in the tropics well marked rainy and dry seasons often determine the season of transmission. Where the vector species breed in ponds transmission occurs in the rainy season, but malaria is acquired in the dry season where the important vectors breed in pools along watercourses. Thus, in Panama, Costa Rica, and El Salvador, malaria follows the onset of the rainy season because the principal vector, *A. albimanus,* breeds in sunlit pools and ponds (Kumm and Zuniga, 1944); and *A. pseudopunctipennis,* which breeds in residual stream pools and seeps, is most abundant in the dry season but is a poor vector. In the Balkans and in the Middle East, *A. superpictus* transmits malaria in the dry season as its larvae develop in stream pools. When the rainy season begins, the larval stages are flushed from the breeding areas. A successional parade of *Anopheles* species was observed by Russell and Rao (1941) in Madras where, with the progress of the season, almost every month was characterized by a different species attaining its maximal seasonal abundance.

The feeding behavior of anophelines is very well fitted to disease transmission. Normally, a fertilized adult female takes its first blood meal (which might be infective) within a few days after emergence. About four days to a week later at summer temperatures the blood is digested, a complement of ova has been matured and deposited, and we are again confronted with a hungry adult. The taking of another blood meal results in the development of another complement of ova. This cycle may be repeated a number of times; seven to ten separate batches of ova developed from as many blood meals have been deposited by *A. punctipennis* and *A. quadrimaculatus* in the laboratory (Bellamy and Repass, unpublished). Shute

[1] Contribution from the George Williams Hooper Foundation for Medical Research of the University of California and the Communicable Disease Center, U. S. Public Health Service, Department of Health, Education, and Welfare, Atlanta, Georgia.

(1936) obtained as many as fifteen batches of ova over a two month period from isolated colony specimens of *A. atroparvus.* The importance of such repeat feeding phenomena relates to the fact that at room temperature the (extrinsic) incubation period of the common plasmodia in *Anopheles* is over two weeks for *Plasmodium vivax* (the shortest), and for *P. malariae* (the longest) about thirty-five days (Boyd and Stratman-Thomas, 1933). At higher temperatures the incubation period is shortened, but it is obvious that there must be a considerable interval between an "infective" blood meal and an actual transmission. In view of these long incubation periods, survival of the vector is also seen to be of extreme importance. Undoubtedly, the failure of some species of *Anopheles* to serve as efficient vectors reflects an insufficient average longevity. The absence of quartan malaria from the Nile Delta of Egypt may be attributed to insufficient survival of *A. pharoensis* to embrace the long incubation period of *P. malariae* (Bates, op. cit.). Longevity is generally much greater in cold and humid seasons than in hot dry weather, but the extrinsic incubation period is also lengthened by cooler temperature. It is interesting that the extrinsic incubation period of bird malaria may be relatively short; Rosen and Reeves (1954) report sporozoites in the salivary glands of *C. tarsalis* four and five days after these mosquitoes fed on canaries infected with *P. relictum.*

Some species of *Anopheles* have very domestic habits which are an important factor in determining their efficiency as malaria vectors. Thus, *A. gambiae,* probably the most efficient of all malaria vectors, is extremely domestic, congregating and feeding almost exclusively in human habitations; Holstein (1954), however, reports that some populations of this species appear to be less domestic. *A. atroparvus,* the "shortwing" of Swellengrebel and de Buck (1938), virtually overwinters in bedrooms of unheated attics in North Holland. As the mosquitoes cease reproductive activity early in the autumn but continue to feed periodically (gonotrophic dissociation) without leaving the unheated attics, malaria was transmitted primarily in the autumn and early winter (later in the season—mid-January to April—only degenerate sporozoites were found). In the arid, rocky hill country in the vicinity of Jerusalem in Palestine (Israel), malaria transmission was found to result from peculiarly domestic vector relationships of *A. claviger,* a species which elsewhere does not have domestic habits. This species breeds in cool waters generally, and in this locality passed its larval stages in the cool subterranean water held in the ancient cisterns carved in rock under the houses. On emergence, the adults fed repeatedly on the family occupying the chambers above the cistern and transmitted malaria (Kligler, 1930). In contradistinction, some species of *Anopheles* are very wild and remain in the vicinity of the marshes or swamps which are their breeding areas. Still other species are intermediate, entering houses at night to feed, but returning promptly thereafter to the forest. The importance of such a sylvan species (examples: *A. minimus flavirostris* in the Philippines (Puri, 1949); *A. maculatus* in Malaya (Buxton and Leeson, 1949) as a malaria vector can easily be underestimated because its association with man is not conspicuous.

Anophelines have radiated into a wide variety of breeding areas, some being species adapted to flowing water, others to ponds, some to open marshes, others to wooded swamps, etc. Brackish coastal marshes are the habitat of some, while a few occupy the water held in tree holes, the internodes of bamboo, or in tropical airplants.

While it has been the hope of medical entomologists to established a malaria transmission threshold in terms of vector abundance (or vector measurement), the countless variables always applicable, even in the simplest situations, have precluded any exact solution to this problem in any area. A relatively small population of an extremely efficient vector may serve to transmit malaria, while larger populations of less efficient vectors are necessary. *A. pharoensis* is a poor vector but transmits malaria in the Nile Delta area of Egypt, where it is extremely abundant. Small populations of *A. sergenti* at Egyptian oases must be eyed with apprehension.

Nearly all species of *Anopheles* that have been adequately tested have shown some degree of infection with human plasmodia, but some species appear to become infected much more readily than others. In fact, there appears to be considerable variation in the suspectibility of different species of *Anopheles* to the several species of human malaria and to different strains of the same species. An anopheline susceptible to infection by a local strain of a given species of *Plasmodium* may be refractive to a foreign strain of the same species (James, Nicol, and Shute, 1932); however, the predilection of a vector for infection by local strains is not universal (Boyd, 1940). By selection and segregation of the genetic lines, Huff (1929) obtained strains of *Culex pipiens* (probably *molestus?*) which differed in susceptibility to infection with bird malaria. Kitzmiller (1953), in reviewing various reported instances of strains of a given species of mosquito differing in susceptibility to infection by one or another parasite, considers the genetic significance.

Various studies of the flight habits of *Anopheles* indicate that in general a vector species in the tropics will not travel over a mile from its breeding area in numbers sufficient to be important; in the temperate zones transmission may occur two or three miles from highly productive breeding areas (Russell, *et al.,* 1946). In Palestine, *A. sacharovi* flies to villages more than five miles from its breeding grounds in the Huleh Marsh (Kligler and Mer, 1930); apparently this long flight occurs only in the autumn when the mosquitoes are seeking hibernation sites. Freeborn (1949) describes ten-mile pre- and post-hibernation flights of *A. freeborni* in the Sacramento Valley of California. Such lengthy pre-hibernation flights in some instances appear to result in malaria transmission.

YELLOW FEVER. *Aedes aegypti,* vector of urban yellow fever and the principal vector of dengue, is of more or less circumglobal occurrence in tropical and subtropical regions; however, as a result of intensive control measures, it is being eliminated from much of tropical America. This mosquito will feed on a wide variety of vertebrates but is fond of human blood and is normally intimately associated with man. *A. aegypti* has attained the ultimate in domesticity, particularly in the New World. The chosen breeding sites are flower vases and small accumulations of water in other containers, usually inside the house, but occasionally outside close by. Vases are particularly suited, since the eggs are deposited at, or just above, the water level and hatch when water is added to the vase.

A sequence of interesting discoveries in the late twenties and early thirties forced abandonment of the old concept of yellow fever as a disease restricted to urban centers and transmitted solely from man to man by the house mosquito, *A. aegypti.* It was found that yellow fever virus was infective to monkeys, and that even laboratory mice were subject to infection if inoculated intracerebrally. Also, several species of mosquitoes were found to be capable of transmitting the virus experimentally. Then, early in 1932, a rural epidemic of yellow fever occurred in Esperito Santo, Brazil, where transmission by *A. aegypti* could be ruled out (Soper, *et al.*, 1933). Further studies filled in the concept of a disease cycle in animals of the dense forest in Africa and in South America; this came to be known as Jungle Yellow Fever.

The discovery in Colombia in 1940 (Bugher, *et al.*, 1944) that the principal vector of jungle yellow fever, *Haemogogus spegazinii,* normally confines its activities to the forest canopy or tree-top stratum, was of extreme importance in helping to interpret the natural disease cycle and in dictating the nature of further field studies. Since then, studies of mosquitoes biting at platforms in tree tops as well as at ground level, and often at an intermediate understory level, have been extensively utilized in yellow fever investigations both in Africa and South America (Galindo, Trapido, and Carpenter, 1950).

Haddow (1954) has reported on very extensive studies in Africa based on the capture of mosquitoes alighting to bite at platforms constructed at different levels in the forest. On the basis of several years' experience, he emphasizes the importance of executing the collections through a full 24-hour cycle, as well as at several different levels in the forest simultaneously. A whole battery of collectors, supervisors, cooks, and other workers are utilized in performing this type of collecting, and the collectors are rotated so that some are resting while others are at work. Haddow *(op. cit.)* reports the capture of 107,567 mosquitoes in such studies carried out over a seven-year period; this was an average of about one and a half mosquitoes per man hour of collecting effort. While the investment represented by the human effort which went into these investigations was enormous, some very enlightening data on the patterns of feeding activity of a number of species of mosquitoes was obtained. Some species were found to confine their feeding activities to the daylight hours, while others were crepuscular, and still others nocturnal. Of the nocturnal species, some fed early in the night and others mainly after midnight. A species might feed most actively at ground level during one hour but at the understory or canopy stratum later, indicating a vertical migration.

In attempting to account for the biting (or feeding) patterns of mosquitoes, Haddow *(op. cit.)* subscribes to the view that instead of there being certain climatic or meterorologic stimuli causing mosquitoes to bite, they feed when "released" from certain inhibiting factors. In this sense, high temperature and sunlight may inhibit the activity of a nocturnal species and thus determine the hour that it may begin seeking blood. Obviously, the choice of host (e.g., bird rather than mammal, or mammal rather than an inanimate object) to bite, must be considered in terms of response to certain stimuli (heat, odor, carbon dioxide gas, motion) evolving from the host.

The isolation of yellow fever virus from certain forest species of mosquitoes, demonstration in the laboratory that such species may serve to transmit the virus from monkey to monkey, studies of the incidence of immunity to yellow fever in populations of monkeys and in other forest vertebrates, and studies of the distribution, life history, and biting habits of various mosquitoes, have permitted epidemiological interpretations of jungle yellow fever in Africa and South America. In east Africa it appears that yellow fever is transmitted from monkey to monkey by *Aedes africanus,* a mosquito of the forest canopy. At times, hordes of monkeys make raids on plantations which occupy clearings in the jungle. *Aedes simpsoni* breeds in the water held in the leaf axils of banana plants and is an abundant species about the banana plantations. At the time of a raid on a plantation, a monkey circulating yellow fever virus may be bitten by specimens of *A. simpsoni* which would become infected as a result. In turn, the infected *A. simpsoni* may transmit yellow fever virus to human beings at the plantation (A. J. Warren: in Strode, 1951). Once the virus is established in human beings, *A. simpsoni* and *A. aegypti,* if present, may transmit it from person to person. In the West Nile District of Uganda, Lumsden and Buxton (1951) found no evidence of human-to-human transmission (via a vector), since in a survey of human sera the small number which showed immunity were all from men (transmission in a village would not have been restricted to the male sex).

It appears that the jungle cycle is very similar in South America, with *Haemogogus spegazinii* and *Aedes leucocelaenus* serving as primary vectors. These mosquitoes feed most actively at midday, and *A. leucocelaenus* is not so restricted to the canopy stratum as is *H. spegazinii.* Laborers near the edge of the jungle may enter the forest to eat their lunch in the shade and thereby expose themselvs to infective bites of the diurnal yellow fever vectors. Persons felling trees, such as woodcutters and roadbuilders, are especially vulnerable since, as a tree falls and drags to the ground a portion of the canopy, the canopy-inhabiting mosquitoes may follow the foliage earthward and feed at ground level on the woodsmen.

FILARIASIS. *Wuchereria bancrofti* and *W. malayi* are the two species of filarial worms known to be transmitted to man by mosquitoes. *W. malayi* occurs in southeast Asia and the Dutch East Indies, while *W. bancrofti* is widely distributed in the tropics. Characteristically, the microfilaria (the stage infective to mosquitoes) occur in the infected human's peripheral circulation at night—usually before midnight in the case of *W. bancrofti* infections—but during the day are scarce or absent from the peripheral blood. *Culex quinquefasciatus (-fatigans)* appears to be the principal vector of this periodic form of *W. bancrofti; C. quinquefasciatus* does not ordinarily feed until an hour or more after dark. Thus, the periodicity of microfilaria in the peripheral blood flavors the infection of a nocturnal mosquito such as *C. quinquefasciatus;* several species of *Anopheles, Mansonia,* and *Aedes* which also are night feeders may serve in a vector capacity. A race of *W. bancrofti* which occurs in the South Pacific area shows no periodicity in the invasion of the peripheral blood by microfilaria, but is morphologically indistinguishable from the periodic form of *W. bancrofti. Aedes polynesiensis* and other day-biting members of the *Aedes scutellaris* complex transmit the nonperiodic form of *W. bancrofti* in the Polynesian Islands. The water standing in coconut shells which have been opened by rats serves as the principal habitat of the larvae of *A. polynesiensis* in the Society Islands (Rosen, 1954). Nocturnal periodicity of circulating microfilaria occurs in *W. malayi* infections, but the periodicity is less clear-cut than is the case with the periodic form of *W. bancrofti. W. malayi* may be transmitted by several species of *Mansonia* and *Anopheles.*

ARTHROPOD-BORNE ENCEPHALITIDES. Quite a group of neurotropic viruses have been obtained on the several continents by the technique of grinding and inoculating into the brains of mice the crushed cell contents of blood-feeding arthropods—particularly mosquitoes. Thus Venezuelan Equine Encephalitis, Ilheus virus, *Anopheles* A and *Anopheles* B viruses, and others are known from South America. Bwamba Fever, Rift Valley Fever, West Nile virus, Semliki Forest virus, and others are known from Africa. Japanese B Encephalitis virus occurring in Japan and adjacent areas of continental Asia produces a serious, often fatal, disease in man. Eastern Equine Encephalomyelitis, Western Equine Encephalitis, and St. Louis Encephalitis in the United States similarly produce serious clinical manifestations in man. California virus, though little known, may possibly produce a clinical disease in man (Hammon and Reeves, 1952); several of the above viruses, however, are not known to do so. In California, the viruses of Western Equine Encephalitis (WEE) and St. Louis Encephalitis (SLE) cause a sufficient amount of human disease annually that they constitute a serious public health problem.

The preponderance of evidence from the studies in California points to *Culex tarsalis* as the primary vector of both WEE and SLE. *C. tarsalis* appears to be the sole important vector of WEE in California, but there is some indication that *C. quinquefasciatus* may participate significantly in the transmission of SLE, though unquestionably much less than *C. tarsalis.*

Thus, *C. tarsalis* is an extremely important mosquito in California and, perhaps to a lesser extent, in the western states generally. In the case of both WEE and SLE it appears that in the principal cycle the virus is transmitted from bird to bird by *C. tarsalis*. Man, horse, and other mammals are occasionally infected when an infective *C. tarsalis* elects to feed on such mammalian hosts. Mammals, however, appear to represent a cul-de-sac for the virus, as mammals do not circulate virus in the high concentrations needed to infect mosquitoes (Reeves, 1945). Birds circulate virus at an infective level. *C. tarsalis* fits this cycle very well as it is predominantly aviophilic; this was shown for populations of this mosquito in Washington (Reeves and Hammon, 1944) and in Kern County, California (Hammon, Reeves, and Galindo, 1945), by the precipitin test technique. These tests also indicated that smaller but significant proportions of the *C. tarsalis* populations were feeding on such mammals as horses and cows. The demonstration of bird malaria infection in a significantly large proportion of adult female *C. tarsalis* collected in Kern County (Reeves, et al., 1954) indicated that this mosquito was feeding on wild birds to a marked extent. Still another technique, that of staining and examining the smeared blood meal of blood-engorged specimens collected in the field, has shown nucleated erythrocytes in nearly all of a series of over a hundred *C. tarsalis* tested in the spring of 1954 (unpublished data); the preponderance of blood meals showing nucleated erythrocytes in this particular series from Kern County strongly suggests that birds were the source of blood, although cold blooded vertebrates also have nucleated erythrocytes. Belkin, *et. al.* (1945) utilized the above technique in obtaining data on the feeding habits of *Anopheles lungae* in the Solomon Islands. Numerous unpleasant observations attest to the willingness of *C. tarsalis* to feed on man; the old controversy over this question which formerly raged in meetings of the California Mosquito Control Association (Reeves, 1951) is now settled.

While the biting (feeding) of *C. tarsalis* has not been investigated comprehensively throughout the 24-hour cycle, an abundance of observations indicate that this mosquito is active at night. It bites man, it comes to traps baited with birds of with carbon dioxide, and it comes to light traps—all at night. During the day, adults are found resting inactive in various sheltered places where they are protected from sunlight and air currents. When disturbed in such resting places, occasional individuals may elect to bite the investigator, particularly on humid mornings. By using dry ice baited lard-can traps (Bellamy and Reeves, 1952) and alternating the traps at a single location throughout a late summer night in 1951, evidence was obtained that (at least on that night) adult females were attracted to the carbon dioxide at all periods of the night. Almost none was attracted in the hour before sundown. The largest number came in the first hour after sundown, and the next largest during the hour before dawn. Somewhat smaller numbers were taken in the hours before midnight and in the hours after. The same technique *(op. cit.)* demonstrated that *C. tarsalis* was attracted in numbers to the dry ice baited traps operated 20 to 30 feet above ground in the foliage of trees. This may be a reflection of the probable habit of this species of feeding on birds roosting in tree tops, and is reminiscent of the feeding habits of the sylvan vectors of jungle yellow fever.

In Kern County, California, *C. tarsalis* appears to complete several generations in the spring, summer, and fall, probably not over ten. Overwintering females begin taking blood in January (Brookman, unpublished). From January to March a high proportion of overwintering females are seen to be feeding, developing eggs, and, presumably, ovipositing. By using the appearance of males as a guide, we must conclude that the first spring generation of consequence takes wing in April; it is usually May before adults are plentiful, perhaps late in May, although some early individuals emerge in March. Blood-feeding in the latter months of the year is minimal, and males persist into December. The observed cessation of feeding in the autumn and the resumption of feeding activities in January has a special significance in relation to a possible overwintering mechanism of the encephalitis viruses.

While on the subject of blood-feeding by *C. tarsalis,* we should not neglect the very important matter of repeat feedings. A first feeding serves only to infect a mosquito; for transmission to occur, a repeat feeding after an appropriate extrinsic incubation period of about ten days (Hammon and Reeves, 1943) is necessary. There appears to be considerable reluctance on the part of *C. tarsalis* to take a second blood meal, though Hammon and Reeves *(op. cit.)* had considerable success. Difficulties in inducing refeedings by a laboratory colony strain of this species are reported by Hubert, *et al.* (1954), who obtained a maximum of 3% refeedings on any single "offering" and not more than an aggregate of 15% "throughout a cycle of repeated offerings." If this tendency is reflected in the wild populations of *C. tarsalis,* it may be the most important factor limiting the efficiency of this species as a vector of encephalitis.

Vector density appears to be extremely important in determining transmission of encephalitis in epidemic proportions. In the spring of 1952 the largest Sierra snow pack on record began melting and running off into the San Joaquin and Sacramento Valleys. Surplus water was the general condition throughout the Central Valley in the late spring and early summer; this was accompanied by unusually large populations of *C. tarsalis* throughout the area. Both horse and human cases of WEE were soon to appear. While large vector populations appear to favor increased transmission, it is not possible at present to state (even roughly) in terms of some measure of vector abundance just what the transmission threshold might be. Various measures of the abundance of adult *C. tarsalis* currently being taken at selected points in the Central

Valley (by members of the associations convened here) may permit the development of important threshold concepts.

Studies were performed (Reeves, *et. al.*, 1948) on the flight range of *C. tarsalis* in Kern County. It was indicated from these studies that *C. tarsalis* would fly at least 2½ miles. In considering control of a disease vector, its effective flight range is an important consideration.

A final word on the long-term reservoirs of mosquito-borne diseases. In the case of malaria, chronic-carrier phenomena and relapses permit man, the vertebrate host, to serve as an effective reservoir. In filariasis, again man can serve as a long-term reservoir over periods in which there is little vector-vertebrate host contact. In yellow fever the answer is not so clear, but students of this disease appear to feel that there may be lateral movement of the disease from place to place in the tropical jungles with more or less continuous transmission. Because of the development of immunity by the vertebrate hosts, students of yellow fever would explain the tiding over of virus through any periods unfavorable for transmission, as accomplished in long-lived vector mosquitoes which enter the period infected. In the study of WEE and SLE in California we are attacking the long-term (or overwintering) reservoir problem. Some leads have been obtained, but we are not yet in a position to say whether a vertebrate or a mosquito or both may account for virus overwintering.

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THE ROLE OF TAXONOMY IN RELATION TO ECOLOGY AND CONTROL

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The purpose of taxonomy is the interpretation of the relationships of living things along with the naming of the entities involved. It is only when this first step has been taken that meaningful information on biology, ecology, geographical distribution, and control can be put to useful purpose. Ideally, a systematist studies an unnamed form and describes it so thoroughly and concisely that it can be readily recognized. Next, its life history, seasonal history, ecology, distribution, and all the other peculiarities which are part of its identity are described by specialists in those fields. Then, if it is a species of economic importance, the results of control efforts by mechanical, chemical, or biological means will be published. Finally, cataloguers and abstracting journals will assemble and condense the pertinent information. The result in this ideal situation is that anyone furnished with the identification of a specimen of this species can discover in the space of a few minutes to a few hours of library research the data accumulated by many workers over the years.

Unfortunately, few of the million or so species of insects are adequately described, and many are yet to be recognized. Of the named forms but a small percentage have an appreciable amount of associated biological information. Comparatively speaking, mosquito workers are very well off in this respect. Because of the medical and agricultural significance of so many species, a wealth of data is available.

Taxonomists can claim only a small share of the credit even though their part was the essential first step. In fact, it might be said that information on ecology, distribution, control, etc., was gathered in spite of the fumbling efforts of many early taxonomists. At times the sequence has been reversed and clarification of the taxonomy has followed the discovery of puzzling ecological inconsistencies in such things as breeding places and adult biting habits. Even with all of the mistakes, however, Culicidology now occupies a favored position in Entomology.

Entomological examples of the interdependency of taxonomy, ecology, and control are many. One of the best known concerns the California red scale, *Aonidiella aurantii* (Mask.) and the yellow scale, *A. citrina* (Coq.), on citrus. For many years the two were considered practically identical, and it wasn't until 1937 that McKenzie pointed out definite structural differences. The ecology and biology are quite different, however, and biological control efforts must take this into account. For instance, two of the common chalcid parasites of the yellow scale will not develop on red scale. Control of red scale is important because it attacks the twigs and branches, frequently killing them. Yellow scale is of rather minor importance and avoids the citrus wood. It appears obvious from the foregoing that efficient scale control is dependent upon a knowledge of the ecology and taxonomy of the species involved.

Another example of the danger of confusion of two closely related species when one is of economic importance has been reported by Lange and Michelbacher (1937). In tomato fields of California the corn earworm (tomato fruitworm), *Heliothis armigera* (Hübner) is a serious pest. A very similar species, *Heliothis phloxiphaga* G. and R., primarily attacks tarweed but is frequently seen about tomato fields and mistaken for its more notorious relative. Adults of *phloxiphaga* appear earlier in the season than those of the corn earworm, and field investigators, aware of the distinction, have learned to ignore them.

Examples in the field of mosquitoes could likewise be given at length. In the case of *Aedes aegypti* (L.) and *A. guamensis* Farner and Bohart on Guam, the first species was the carrier of dengue in epidemic proportions during World War II. The two species are separable by small but definite structural characters in the larvae. As a consequence, it was found that *aegypti* bred only in containers close to dwellings and that *guamensis* occurred from the deepest jungle to within 100 feet of dwellings. *Aegypti* was an important pest and *guamensis* could hardly be induced to bite man, so control was concentrated on larvae near dwellings with the result that *aegypti* was eradicated (Bailey and Bohart, 1952).

Another example in the Pacific Area deals with the complicated *Aedes scutellaris* group, the 15 or more species of which range extensively over Polynesia, Micronesia, and Melanesia west nearly to the continent of Asia. It was once thought that the various forms were local color varieties or perhaps subspecies. As evidence built up from field workers on the radically different habits of forms on different islands, and as museum workers discovered small but constant structural differences in material sent in for identification, it became clear that a number of closely related species were involved. This conclusion has been strengthened by evidence of differences in ability to transmit filariasis, and control efforts have been modified accordingly.

A similar but better known case concerns the *Anopheles maculipennis* complex in Europe. The absence of malaria in parts of Europe where *A. maculipennis* Meigen was abundant aroused speculation as early as 1920. This was followed by the announcement by Swellengrebel, de Buck, and Schoute that two populations existed in Holland with different adult feeding habits, adult mating habits, and larval breeding places, but no morphological distinction except a statistical difference in size. An important forward step was made by Martini, Missiroli, and Hackett (1931) who showed that egg pattern differences provided a practical, though difficult, means of identifying the species. Still later work of a genetical nature has established the existence of partial or complete sterility barriers between the different forms. Five or six species with different malaria-carrying potentialities are currently recognized (Bates, 1940).

In the above case and in others where cryptic species are involved it would be simpler from a museum worker's viewpoint to ignore the biological differences, but the taxonomist must state the facts as he sees them. Indeed, from a control standpoint it is absolutely essential that he do so. On the other hand, taxonomists must beware of haphazard splitting without adequate morphological or biological data. Those who have indulged in this practice have created confusion among ecologists and control workers.

In North American *Anopheles* similar problems have arisen and not all have been satisfactorily resolved. In eastern United States there seems to be only one really suitable malaria carrier, *A. quadrimaculatus*. It is distinguished with some difficulty from *A. punctipennis* Say in the larval stage but easily from *A. crucians* Wied. and *A. bradleyi* King. Each of these four has distinctive habits of larval breeding and adult biting. Although much malaria control has been misdirected at the last three species, successful programs backed by a knowledge of taxonomy and ecology have concentrated on *quadrimaculatus*.

One taxonomic problem which is yet to be clarified is the *Anopheles pseudopunctipennis—franciscanus* complex in North and South America. The more southern and eastern form, *pseudopunctipennis* Theo. (s.s.), bites man readily, has white-tipped palpi and larvae with spiracular projections. The more northern and western form, *A. p. franciscanus* McCr., has black-tipped palpi and larvae without spiracular projections. Its biting habits are open to question although it has been generally assumed not to bite man to any extent. Observations of Belkin, Ehmann, and Heid (1951) throw doubt on this point, however. To confuse the picture there are several egg types in both the typical form and in *franciscanus*. Reasoning from these as well as from observed variations in ecology, it may be that *franciscanus* can be divided into cryptic species one or more of which might deserve some control effort. It should be said that present evidence does not strongly support this hypothesis, however.

In California there are three species of *Culex* which resemble each other closely either as adults or as larvae. These are *C. tarsalis* Coq., *C. stigmatosoma* Dyar, and *C. thriambus* Dyar. They differ in adult biting habits and in larval breeding habits. *C. tarsalis* is the most common and is an important known vector of encephalitides. *C. stigmatosoma* very rarely bites man but is frequently numerous. *C. thriambus* is a shy and rare creature with unknown biting habits. Control efforts have been concerned only with the first two, and the value of controlling *stigmatosoma* in very foul water where it occurs in practically pure culture is a matter of present debate. Furthermore, the ecology of *tarsalis* has been thought by some to be undergoing a change, with a tendency toward breeding in foul water. Current ecological studies should provide us with more exact information on this subject. Also needed, however, is an evaluation of the importance of *stigmatosoma* to its warm-blooded, non-human hosts. Until these questions are answered a certain proportion of control effort is bound to be inefficient.

An interesting situation exists in the salt marshes of central California. Here *Aedes squamiger* Coq. and *A. dorsalis* Meigen share honors as severe pests of man. Until recently (Bohart, 1948) the larvae were indistinguishable by any reliable characters, and the gathering of information on the larval ecology was hampered by the necessity of laborious larval rearing. Now, the larvae can be distinguished by a glance at the saddle hair, long in *squamiger* and short in *dorsalis*. It is now known that *squamiger* larvae occur in a series of overlapping hatches through winter to early spring, and *dorsalis* has a succession of generations from spring to fall. Thus, a winter larvicide program would kill appreciable numbers of *squamiger* but not *dorsalis*, and a summertime larvicide program would kill *dorsalis* only. Furthermore, a springtime marsh-fogging operation could conceivably be effective against *dorsalis* adults, which tend to stay on the marsh, but not against *squamiger*, which fly quickly to the hills after emergence. When all of these things are taken into account, control by chemicals becomes a complicated matter. Luckily, both species are susceptible to marsh drainage projects, and these with the impetus of housing developments are reducing the problem.

The role of taxonomy is not always understood by the self-styled "practical" mosquito control worker. This "practical" worker believes that all mosquitoes are injurious irrespective of their taxonomy or ecology. He has a tendency to look on the taxonomist as a name juggler in an ivory tower. He argues that a control operator cannot waste time counting hairs on mosquito larvae in a mud puddle. He kills all the larvae and adults he can reach as rapidly as he can get to them. Occasionally, some of these ideas creep insidiously into the thoughts of intelligent men. The fallacy of the argument is that there always seems to be too many mosquitoes to make it possible to kill them all. In the attempt to do so, time and money are unnecessarily expended on relatively innocuous species and unproductive sources, while important ones are neglected. In the necessary restriction of control efforts, taxonomy and ecology must take a vital part. On the level of a mosquito control district the solution is simply this: The entomologist must be aware of the identity of all the mosquitoes in his area. He must know the biology of each so well that he can visualize all of the suitable breeding places for the larvae, hiding places for the adults, and deposition sites for the eggs. Armed with this knowledge gained by an intensive field study of his area together with up to date published information, he can help the control operator pin-point his efforts on the sources of the injurious species. Thus, through the application of taxonomy and ecology, thousands of hours of useless yet expensive labor may be avoided, and emphasis can be directed toward areas of potential danger.

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ECOLOGICAL BY-LINES OF AN ALASKAN MOSQUITO WORKER

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Biological knowledge of 24 mosquitoes belonging to *Aedes, Culiseta, Culex,* and *Anopheles* in Alaska is rather new and sketchy. To be sure, the taxonomist has contributed fairly adequate descriptions so that the larvae and males, at least, may be identified. And rapid progress is being made, especially in Canada, by discovering characters for identifying the all-important females of *Aedes*. On this taxonomic framework field workers have begun to build knowledge of how northern mosquitoes live and how to destroy them, too. The Alaska Insect Project, for example, undertook an extensive survey of mosquitoes, 1947-50, which not only developed a practical control method for large military installations, but also provided an up-to-date check list and phenological and habitat information. The author began as a Cheechako with the Alaska Insect Project in 1948 and stayed on after its close.

The present paper views northern mosquitoes in the light of recent knowledge but does not attempt a summary of it. Rather, certain of the author's own findings are classified from an ecological bias to emphasize broad topics like life cycle, distribution, and habits at the expense of detailed data. Marston Bates' and Muirhead-Thomson's natural histories lifted mosquito ecology above mere lists of organisms, tables of physical-chemical data, and new terminology. They "hazarded analysis on a higher level of abstraction rather than (being) so much preoccupied with the purely technical collection of data." And they showed for mosquito studies what Bridgman was saying about nuclear physics, that "it is better, because it takes us further, to analyze into doings or happenings rather than into objects or entities."

Alaska is a favorable country for studying mosquito behavior. Though there may be no endemic species of mosquitoes in the northern Territory, many kinds reach great abundance there. Familiar examples, rare elsewhere, include *Culiseta impatiens* and *alaskaensis* and the northern salt-marsh breeder, *Aedes punctodes*. The influence of extreme temperatures, high as well as low, and of the inversions important in mosquito behavior and control can be investigated under natural conditions. Among ice cakes, one may dip wigglers which will appear on the wing at perhaps 96 degrees F. The horizontal setting of the midnight sun prolongs swarming of crepuscular males and facilitates observations. Alaskan mosquitoes, like the moose and bears, are feral, and nature is still natural.

ECOLOGICAL GROUPS

It is instructive to separate mosquitoes into ecological groups manifesting different life cycles. Apparently, all Alaskan mosquitoes are single-brooded with an obligatory diapause. In the majority group, comprising 18 species of *Aedes,* the hibernation stage is the egg. Wesenberg-Lund and Marston Bates have designated this familiar type of life history the *Aedes cinereus* cycle. *Cinereus* itself is a common species in Alaska. In a minority type of cycle, four or more species belonging to *Culiseta, Culex* and *Anopheles* hibernate quite differently as adult females. I proposed this new type of life history be named the *Culiseta impatiens* cycle. The common characteristics of these taxonomically miscellaneous species will be discussed presently. They are quite similar ecologically, even, for example, in their aquatic habitat preferences. What specific differences there are emphasize rather than hide a fundamental identity of type. The biological groups have proved to be a useful concept. Other types of mosquito life cycles have not been found in Alaska, and, since single-broodedness is exceptional rather than the rule farther south, the classification also emphasizes the most general difference setting northern mosquitoes apart.

MOSQUITO DISTRIBUTION

Mosquitoes of temperate, subarctic, and especially of arctic Alaska represent a larger selection biota of cold-tolerant holarctic organisms. Low temperatures are the country's chief limiting factor. Of course, fewest species occur in (1) *the arctic* where the entire local mosquito fauna may consist of three or four species of *Aedes,* particularly *punctor* and *communis,* which abound and produce a terrible pest problem for about four weeks per year. Nowhere else are so few species so numerous. This accords with the principle that the number of species decreases, of individuals increases toward the poles. In brushy valleys of the arctic, sheltered by miniature aged willows, a few *Culiseta alaskaensis* may represent the minor type of life cycle relying on adult hibernation. (2) Temperate, maritime, Southeastern Alaska is cooler in summer than the subarctic. Only 13 mosquitoes have yet been found, of which nine are *Aedes,* four *Culiseta. C. incidens* and *maccrackenae* are known to occur in Alaska, there only; but *C. alaskaensis* is absent except at transitional Haines, the locality where *Culex territans* also has been collected. *Anopheles* has not been found in Southeastern Alaska. In (3) subarctic Alaska, fly all but two of the mosquitoes of the Alaskan check list, reflecting warm summers. Wickersham (1938) claims Fairbanks has about 1800 hours of sunshine in the 100 day period, May 20-September 1, as compared with 1500 hours for sunny California. The prevalence of mosquitoes with the *Culiseta impatiens* cycle lengthens the mosquito biting season to four months. The alpine parts of subarctic and temperate Alaska are bleak. Nevertheless, the highlands above timberline support typical subarctic as well as arctic mosquitoes which seem to have an eye for habitats rather than meteorology. At McKinley Park in 1954, for example, the predominant alpine species was the benign *Aedes pullatus,* a subarctic species which favors barren pools of glacier aprons and intermittent streams.

Culiseta impatiens CYCLE

This minor type of mosquito life history combining single-broodedness with an obligatory diapause by the inseminated, cold-hardy adult female was recognized as new about 1950 from field observations and the behavior of a laboratory colony of *C. impatiens.* This species and *C. alaskaensis* probably follow the same cycle faithfully throughout their ranges into higher mountains of the temperate zone so that the cycle characterizes them as species. They also are very likely pristine subarctic mosquitoes which survived the ice age north as well as south of the continental glaciers. Thus Natvig (1948) cites distributional evidence for the antiquity in Scandinavia of *C. alaskaensis* which he includes among four mosquitoes he calls "archiboreal." The Alaskan *Anopheles* and *Culex territans* are conjecturably recent converts to the *C. impatiens* cycle, for the identical species yet manifesting the *Culex pipiens* cycle have wide ranges to the south. Very likely adaptation took place *pari passu* with immigration in Pleistocene time when the continental ice sheets were melting.

The adaptations in common permitting mosquitoes with the *C. impatiens* cycle to live in the far north depart widely from corresponding habits of temperate species with the *Culex pipiens* cycle. Hibernation became obligatory for females after mating rather than optional and dependent on a proper stimulus. The diapause was initiated in the warmest part of the summer to include about two months of aestivation followed by eight months of hibernation. This decreased mortality and permitted suppression of the blood lust until after hibernation. None of these species takes blood and manifests gonotrophic dissociation with development of fat bodies for hibernation. Instead of producing several broods per season they require two seasons for a reproductive cycle. Cold tolerance of the female has developed so that months of subfreezing, weeks of -50° F., and sudden fluctuations above freezing are withstood. Her metabolism of digestion and egg production proceed, though slowly, at relatively cool temperatures. *C. impatiens* will engorge at 32 degrees F. and rest afterwards on a snow drift. Oviposition occurred in the laboratory 14.5 days, on the average, after gorging for *C. impatiens,* and for *C. alaskaensis* only after 32.1 days. The contrast with tropical anophelines whose time interval lay within a couple of days or even with that of *Culiseta inornata* in the United States, which requires only 5.3 days (Owen, 1942), is striking. This period could not be shortened for either of the Alaskan *Culiseta* with temperatures higher than 65° F. without excessive mortality. The eggs and pupae, creatures of tepid waters, show no appreciable cold tolerance; and the larger larvae stop feeding when the water temperature drops below about 50° F. The cold hardiness of these species is thus a characteristic of the long-lived female. For mosquitoes with the *Aedes cinereus* cycle, on the other hand, eggs, larvae, and sometimes pupae rather than the adults withstand cold.

SWARMS

Interest in swarming of male mosquitoes has been stimulated recently by the thorough physiological study of Nielsen and Greve (1950) in Denmark. Their bold conclusion that swarming and mating are unrelated phenomena could not be left unconfirmed. They saw only three copulations while observing several millions of mosquitoes in swarms; they ignored numerous contrary observations of the literature.

Almost ideal conditions for observing swarms exist in Alaska. The swarming of myriads of newly hatched mosquitoes just before summer solstice coincides with the longest, brightest days of the year. Twilight is long and strong and the swarmers may be watched for hours with the unaided eye. By contrast, in the tropics observations must be made within a few minutes of failing twilight or artificial light used, and the swarming is not concentrated into a short season. In boreal latitudes during the long "horizontal" sunset swarming mosquitoes may be silhouetted against the horizon, greatly magnified by Tyndall effect.

In June 1952 at Auke Bay in Southeastern Alaska, three sites in my garden clearing were the scene of thirty-eight very large swarms of *Aedes punctor,* one of the species studied by the Danes. At the close of that season my son and I reported our observations in Mosquito News, confident that we were well on the road to understanding the significance of male swarms. Now, two years later, we know the problem is complex. In 1952 we determined approximate copulation rates ranging from 25 to 150 per minute. An estimate of hundreds to thousands of copulations per swarm per evening is conservative. Swarming ended in the garden clearing on June 22 for the season. On July 12 and until August 14 thirty-six late *punctor* swarms of a different sort were watched at two sites on the shores of Auke Bay. There were few participants, and very few instances of mating were seen during many hours of observation. From dipping survey data, these July-August swarmers were old males. We designated the swarms "non-functional," rather presuming the function of swarming to be mating. It was reasonable to assume that when the main emergence of late May occurred there were many more robust males and virgin females, and therefore spring mating was at a higher rate than in summer. Later on, the females would be mostly inseminated, the males old, exhausted, or dead, and therefore smaller swarms and less mating were to be expected.

The following season in the Copper River region, swarms of *Aedes communis, cataphylla, excrucians,* and *Culex territans* were observed; but relatively few instances of mating were seen. Each species produced typical swarms at characteristic swarming sites, supporting claims of Dyar and Wesenberg-Lund. Those of *excrucians* only were large with hundreds to thousands of participants; but since that species' swarms are diffuse and occur at dark, the status of mating is uncertain, although some pairing was proved. *Culex territans* swarmed in the open in mid-afternoon. A note published on its diurnal swarming unfortunately omitted reference to the beautiful observations, then unknown to us, of Levi-Castillo on *Haemogogus* swarming in bright tropical sunshine. Nielsen and Greve believed that crepuscular swarming by diverse male Nematocera is the same phenomenon. Surely the swarming habit is far more universal, and these authors were overly impressed with the influence of sunset and sunrise. In Alaska we are observing diurnal swarms of black flies, phorids, and chironomids, and the crepuscular ones of mosquitoes, chironomids, crane flies, dance flies (chiefly *Rhamphomyia*), etc. for hints as to the significance of swarming mosquitoes. Whether the mating dances of Mayflies are due to the same habit is uncertain. We think so. It is difficult to distinguish swarms of the crane fly, *Limonia (Rhipidia) lecontei* Alex., from those of the Mayfly, *Paraleptophlebia debilis* (Walk.), kindly named by Drs. Alexander and Burks. In the main, the 1953 findings were inconclusive as to mating in swarms but provided further details needed to make swarming a predictable phenomenon. The possibility of inducing mosquito swarms like those of the midge *Anatopynia algens* which we moved around with a white linen sheet, is that much closer.

MOSQUITO PREDATION AND SWARMING BY *Rhamphomyia*

The interesting mating habits of certain Empididae or Dance Flies are well known. A humorous article in the New Yorker factually described those *Empis* males which offer a small insect prey or frothy bubble in courtship. In Alaska the swarming habits of several undescribed species of *Rhamphomyia,* which also manifest unfamiliar new types of mosquito predation, have intruded on our observations of mosquito swarms. Mr. Shewell of Canada is describing the new species which we shall simply designate swarm predators and pupal predators. Tuomikoski (1952) of Finland summarizes *Rhamphomyia's* predatory habits. Clearly, those of our Alaskan species, like the species themselves, were undescribed a couple of years ago. It is the males which are predatory. The males of two *Rhamphomyia* species commonly swarm directly above *Aedes* swarms and capture mosquito males and pairs on the wing. Three or four other *Rhamphomyia* species tirelessly skim Alaskan pools, ponds, and lakes to pounce on emerging mosquito pupae. Since we reported mosquito predation of the latter kind from the north, Alexander Hubert (1953) has observed the same behaviour by a different *Rhamphomyia* in Montana.

SWARM PREDATORS

Our involvement with *Rhamphomyia* began in Southeastern Alaska in 1952 when swarm predators, all males, were noticed night after night circling over the swarms of *Aedes punctor.* From time to time one of these Dance Flies seized a male mosquito or a pair. The next year another species was found in Central Alaska preying on the swarms of three other *Aedes.* This second swarm predator was seen to copulate, though rarely. In this way we became familiar with its larger female, which, having bicolored wings, can be distinguished in the air from the smaller male with uniformly infuscated wings. Shortly, female swarms were recognized where much more mating occurred. The females swarmed rather high in the air (10-15 feet) in openings between trees and along a narrow road. It was apparent that for this species the male predatory swarm was a far less important mating site than the non-predatory female swarm. The pairs *in coitu* "settle out" of the swarms and are easily collected. Here is a dipterous swarmer reversing the usual swarming behaviour of the sexes. However, it was noted that on evenings when the mosquito males did not swarm, and long after swarming had ceased for the season at mosquito swarming sites, the *Rhamphomyia* males often swarmed just the same above the empty mosquito swarming site. One is tempted to think predation is their purpose at mosquito swarming sites; but mosquitoes, especially females, are available elsewhere. Considering the occasional copulations and particularly the aggressive behaviour of the swarming *Rhamphomyia* males toward each other, it is concluded that predation is a secondary activity, mating the primary one. However, predation is becoming more important as mating at male swarms becomes vestigial, being transferred to the female swarms. Long search for the female and mating of the Auke Bay species was unsuccessful, but the efforts led to discovery of the *Rhamphomyia* predators of mosquito pupae.

Rhamphomyia PUPAL PREDATORS

The pupal predators tirelessly "buzz" the surface of all kinds of water collections. They stop skimming only for heavy rains, strong winds, or when it is quite dark. I have watched myriads of them skimming on vast Naknek Lake. Mosquito and midge pupae attempting to emerge are harried. The few which manage to hatch at the water's edge usually are seized and carried away before their wings dry. Swatted mosquitoes falling on the water are grappled with and taken off. The *Rhamphomyia* avoid each other as skillfully as bats or swallows, but when one is engaged trying to lift a heavy insect from the water, he may be viciously attacked by others. In the species observed in Southeastern Alaska both sexes were collected over the water. Mating was overlooked. Next season a second pond-skimming *Rhamphomyia* predator was observed in the Alaska Peninsula. The dorsal surface of the abdomen of the female sports a flashy silver-white saddle making the sex conspicuous. Swarming and mating of literally thousands of these skimmers were observed on a dark afternoon in early July. The males ordinarily disregard the females while busy skimming, but where the females swarmed above them in the dense shade over the pool of a swift torrent, mating was observed at close range. Supernumerary males usually interfered with pairs as they flew up and out of the swarm.

The third season two additional pupal predator skimmers were observed in McKinley Park. One of them, a distinctive species, was characteristic of higher elevations; its mating was not seen. The other species of the Park, which may be identical to the Southeastern Alaskan form, was exceedingly abundant just below timber line. Males were observed day after day diligently preying on *Aedes pullatus* pupae in the pools of an intermittent stream. One calm July evening just before dark a difference of behaviour was noticed. Many of the flies were coming and going a foot or two above the water, no longer skimming. Sampled in the net these were mostly females; those still skimming were males; mating pairs were constantly flying away at the female level. This female is drab, but her behaviour was like that of the showy females with silver saddles. The female swarms of both seem strictly comparable to the female swarms of the swarm predator with bicolor wings. Swarming and mating of the drab pupal predator continued into the dark. It was best observed at twilight against the bright reflection of the sky in the water.

To sum up predatory and swarming habits of these five or six *Rhamphomyia*: (1) The males of two species swarm at twilight above male swarms of *Aedes* and prey on male mosquitoes and pairs. Occasionally copulation of *Rhamphomyia* occurs at the predatory male *Rhamphomyia* swarms. Normally, however, copulation takes place at non-predatory female swarms. (2) The males of other species of *Rhamphomyia* are diurnal pond skimmers which prey on emerging mosquito pupae, especially *Aedes picnips, pullatus,* and *punctor*. The non-predatory females swarm by day or crepuscularly for mating purposes over waters favored by the skimming males. Male mating swarms were not found. Apparently the non-predatory females of (1) are assuming the function of swarming for mating, while those of (2) have already assumed that function.

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ECOLOGICAL APPROACH TO STUDIES OF MOSQUITOES IN IRRIGATED AREAS

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The underlying principle of research into mosquitoes and their control in California is the ecological approach. Twenty-eight years ago, in 1926, Freeborn wrote "The real science of mosquito control and the efficient application of control measures rest upon an accurate knowledge of the taxonomy of the group and a thorough acquaintance with the ecology of the species involved." This implies a logical order of study in determining or developing a scientific basis for mosquito control methods.

In California the work of such outstanding and well-known investigators as Herms, Freeborn, Gray, Reeves, Bellamy, Bohart, Belkin, Aitken, Brookman, Thurman, and Husbands, to name only a few, has been characterized by this scientific attitude. It is only thorough and complete understanding of the individual mosquito species, their peculiarities and behavior on a year-round basis, that precise and economical control technology can be assured.

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Ecology is the science of the interrelations between living organisms and their environment. Therefore, in order to understand the scope of ecology in mosquito control, it is essential that the niche occupied by the individual mosquito species be fully understood with respect to both its aquatic and its terrestrial existence. The subject must be considered in relation to other branches of biology and to "ologies" in general.

The prevention of animal-borne diseases of man is often an ecological as well as a medical problem. Odum (1954) states that control of a specific disease carrier is often accomplished more efficiently and cheaply by control of the organism's environment or community than by direct attack on the organism itself.

Mosquitoes have been controlled more efficiently and cheaply by modifying the aquatic community (as by fluctuating the water level, for example). In the TVA control program, Cartrell and Ludvik (1954) observe that chemical control measures have always been considered as supplementary, principal reliance being placed on environmental or naturalistic control methods. The insecticides have served them well pending the establishment of satisfactory environmental methods. They report that there is a continuing need for efficient larvicidal measures for use when emergency situations arise and as a part of the regular control program to obtain the maximum benefit from water level management schedules. Lindquist (1953), in an interesting discussion of biological research on mosquitoes as a basis for their control, notes that mosquito control with chemicals today would be far less successful if we did not have considerable biological knowledge of the pests. He uses the word "biology" in its broad sense to include behavior, habits, and physiology.

In its more scientific aspects, ecology is a complex subject requiring considerable research time in order to arrive at valid conclusions with respect to effective control measures. Gjullin, Yates, and Stage (1950) studied for a number of years two floodwater mosquitoes, *Aedes vexans* (Meig.) and *Aedes sticticus* (Meig.), which inhabit open and wooded lowlands flooded by annual spring peaks of the Columbia River. The last sentence in their summary (page 275) states—"During a period of 18 years a quantity of ecological and biological data was accumulated."

Consequently, a great deal of diligent study of mosquitoes is in order before we can even begin to entertain the idea that we are the masters of mosquitoes, even a single species. It also emphasizes the fact that it is virtually impossible to obtain knowledge of mosquito control on an entirely empirical basis.

Lindquist (loc. cit.) believes that one reason why it is difficult for laymen and persons engaged in mosquito control to appreciate biology is because sound biological research is difficult and slow. He points out, too, that significant developments usually do not come overnight, but only after years of intensive study under exacting scientific methods. Reeves (1950) is of the opinion that as a rule, the discovery of ecological facts falls into one of two categories: (1) If it is a fact which leads to new control methods or is incorporated in existing methods, it is quickly accepted and becomes a part of control procedures; (2) An ecological finding for which no immediate use can be found is frequently regarded sceptically as a scientific oddity and considered the product of an impractical scientist's worthless efforts.

Allee and Co-workers (1950) show that the application of even a well-formulated generalization to a given situation may require further research. For example, in the control of mosquito-borne diseases of man, the mosquitoes that transmit epidemic yellow fever behave according to rule. It is not so with the anopheline mosquitoes that transmit malaria. Each type of malarial vector is a special case, and, without further knowledge, the general principles may seem inapplicable to the given situation. Accordingly, in an adequate mosquito control program, under such varied conditions as exist in California, the needed local detail is of equal value with knowledge of the underlying general principles.

Wallis (1954) points out that in filariasis control in Samoa the usual methods of insecticide application is not practical, and attempts are being made to reduce populations of *Aedes polynesiensis* Marks, by a clean-up program, eliminating the collections of rain water in coconut shells and other containers in which this species breeds.

One of the outstanding examples of the application of scientific information to the control of an insect pest is the remarkable effort to destroy the screw-worm which annually causes millions of dollars in losses. United States Department of Agriculture scientists are working on this problem with Dutch authorities on the Caribbean island of Curacao. In view of the fact that the female mates only once a year and with only one male, research workers are releasing thousands of males made sterile by exposure to gamma rays from radioactive cobalt. Thus, female flies which mate with the sterilized males will deposit sterile eggs.[3]

In the Philippines the control of schistosomiasis, by treating snails with known molluscicides has been suspended in order to carry out ecological studies and learn more about the field aspects of the disease, in hopes of developing more precise control methods.

The Sardinian Malaria Eradication Project was suggested as an application of modern scientific information on a large-scale experimental basis. Plans called for eradication of *Anopheles labranchiae* Falleroni on the second largest island in the Mediterranean having an area of over 9,000 square miles and a population of 1,250,000. The cost of the project amounted to more than six billion lire and was active for more than 4½ years.

Logan (1953) reports that as a result of ERIAAS[4] operations, malaria as a public health problem has been eliminated from Sardinia. It was reported that the number of cases, including primary infections, re-infections, and relapses, was reduced from the maximum of 78,173 in 1944 to 44 in 1950, and 9 in 1951. No new cases were verified in 1950 and of the 9 cases reported in 1951, only one was considered as a possible primary infection. Eradication of the vector was not successful and from the evidence presented, it is apparent that the indigenous *labranchiae* has a whole series of survival characteristics which have been developed over many thousands of years. These characteristics normally make them much more difficult to eradicate than an imported species, such as, for example, *Anopheles gambiae* Gills, in South America.

According to Logan (loc. cit.) "The project focused attention on the shortage of data regarding the ecology and the physiology of anophelines, and the need for more information about the action of insecticides. It also emphasized the importance of research and investigation as a fundamental part of insect control work and the difficulty of extending operations beyond the limits of existing scientific knowledge."

Logan believes that eradication remains a potent,

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[3]Anonymous, 1954. Science 120 (3131): 1087.

[4]Ente Regionale per la Lotta Anti Anofelica in Sardegna.

though expensive, possibility in any situation where man is engaged in raising living standards by the suppression or elimination of harmful insects.

He goes on to state that "eradication should be based on an accurate knowledge of the biology of the vector involved and provision should be made to utilize any equipment or method which seems advisable under the circumstances."

Logan concludes that such a project should not be rigidly confined by time or finance.

Rapid population growth and development necessitates the continuing development of technical knowledge on the highest level possible. Giglioli and Charles (1954) observe that prior to the DDT era, the complex hydrological system and the cultivation of two staple crops in the coastal belt of British Guiana, supplied all the conditions required for the abundant and continuous production of *Anopheles darlingi* Root, in the immediate surroundings of towns and villages. They report that malariometric rates were usually directly proportional to the degree of development of drainage and irrigation works, and, therefore, to the stage of agricultural advancement in each district. They also observed that in the eastern part of this coastal belt, agricultural development was less advanced and the man-made factors which provided the conditions for coastal malaria endemicity more relatively deficient in extent and restricted in their distribution.

The greatest detriment to adequate accomplishment in mosquito prevention and control in California is the limited knowledge concerning the bionomics and ecology of mosquitoes.

Th rapid growth and development of mosquito control in California necessitates the continuing development of technical knowledge on the highest level possible.[5] Contributing to this have been many unforeseen problems arising through the creation of a variety of new mosquito habitats as a result of the State's vast water resources development, agricultural expansion, increased population, and industrial growth. These conditions have led to a continuing demand for operational investigations and research pertaining to mosquito ecology, in order to develop the additional technical knowledge necessary for efficient execution of the control program and the most economical use of the funds provided.

Mosquito problems are not static but are changing with the economic development of the state. For example, the common pasture mosquito *Aedes nigromaculis* (Ludlow), which was unknown in California prior to 1936 is today more numerous in the Central Valley than any other single species and is an important factor in human and animal discomfort. *Culex tarsalis* (Coquillett) is the most widely distributed and common mosquito in the state, largely by reason of its ability to utilize a wide va-variety of artificially created aquatic sources which each year are being increased as to kind, size, and number.

The operational investigations proposal to be conducted in California by the Bureau of Vector Control would be concerned with mosquito ecology and control technology. This would involve a sound, scientific balance of biological, physical, and chemical approaches to each element of study. The California Mosquito Control Association and the Bureau of Vector Control, California State Department of Public Health, have two studies under way: one is concerned with pasture mosquitoes; the other is based on a study of rice field mosquitoes. In addition to these two studies, there are numerous other phases of mosquito control that are in need of additional study.

Cotton fields are known to be productive for undetermined but potentially great numbers of *Aedes* and *Culex*. Of these, the encephalitis vector, *Culex tarsalis* (Coq.) is believed to be the most significant. Cotton plants use varying amounts of water in different localities and under different conditions. The heaviest irrigation is needed in late July, August, and September, when the temperatures are highest and the plants are at the peak of flowering and boll dvelopment. This water use coincides with the peak of mosquito production.

In 1952 the encephalitis outbreak and emergency efforts to control *Culex tarsalis* revealed how inadequate is the understanding of this species. Nevertheless, virtually the entire subvention program is based upon the control of this mosquito. Information on the ecology of *Culex tarsalis* is vital to its control and possibly to the control of encephalitis.

In the mosquito measurement program in California there are several aspects which require development in order to obtain more precise knowledge in determining what level of *Culex tarsalis* population is likely to result in encephalitis. One phase of this study visualizes the need for a reliable device or devices by which to establish a mosquito index based upon standard measurement from one locality to the next throughout the state. In the other phase, efforts would be directed toward developing a method of determining the infection rate, which would be used to guide mosquito control measures in specific localities.

The resistance of mosquitoes, particularly of *Culex tarsalis* to chlorinated hydrocarbon insecticides, is of primary concern. It is obvious that reliable insecticides must be developed and made available to mosquito control agencies for the control of the adult stage and the aquatic stages.

In conclusion, there is an obvious need for additional work in the field of ecology in order to comprehend more fully and thereby to hopefully resolve the problems of mosquito control, as well as those of vector control. This implies a logical order of study in determining or developing a scientific basis for mosquito control methods.

[5]The analysis on mosquito control studies needed in California was taken from a report prepared by a subcommittee of the Vector Control Advisory Committee, with the assistance of staff members of the Bureau of Vector Control. The subcommittee consisted of Mr. Harold F. Gray, Chairman, Mr. C. Donald Grant, Dr. William C. Reeves, and Mr. E. Chester Robinson.

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ECOLOGICAL INTERRELATIONSHIPS IN IRRIGATED PASTURES

RICHARD C. HUSBANDS, *Entomologist*
Cooperative Operational Investigations
California Mosquito Control Association and
Bureau of Vector Control Irrigated Pasture Study

Irrigated agriculture and population development in California by logical sequence brought about the demand for economic and health protection through mosquito control. By the same logical sequence the greatest effort in providing protection was aimed at the major sources of mosquitoes. Among these sources are irrigated pastures. Logical, too, was the development of the realization that ecological studies could assist many phases of mosquito control; education, budgeting justification, programming, farmer relations, cooperation, as well as more efficient control operations and the development of new control methods. To provide this assistance the irrigated pasture study was initiated in 1949. Under the inspiring leadership of Deed C. Thurman and the extremely capable assistance of Earl Mortenson, great strides were made toward fulfilling the initial goal of the study.

Within the framework provided by the funds and personnel available the study was designed to place most of its effort upon the investigation of single pastures. Ecological studies are generally devoted to a study of individual species and usually the study of a specific area, such as an irrigated pasture, is not looked upon with great favor by some leading ecologists. However, under the circumstances, the relationship of the problem to specific difficulties in mosquito control and in agricultural methods made this area (irrigated pasture) study practical.

Thus, the irrigated pasture study can be described as an area study which placed major emphasis upon a limited description of the niches available to three important species of mosquitoes; *Aedes nigromaculis* (Ludlow), *Aedes dorsalis* (Meigen), and *Culex tarsalis* (Coquillett). The interrelationships between species and their environment in irrigated pastures could be examined in detail in limited areas within the pasture or could be applied to state-wide ecological problems. For this purpose the study obtained information from (1) small areas within a pasture (limited areas); (2) from single pastures; and, (3) from a comparison of several pastures. This information could be applied to (4) county or abatement-wide areas; and (5) to state-wide areas involving the development of water resources, irrigation, and pasture agriculture.

Types of limited area studies that act as building blocks for ecological measurements can be cited. For example, in 1950 D. C. Thurman, et. al., measured water temperatures in limited areas and found that it influenced larval habits. In vegetated areas shallow standing water exhibited considerable variation in temperature from top to bottom. This was considered to possibly influence larval feeding habits, rates of growth, and the gregarious habits of certain instars of *Aedes* species larvae. Theoretically it could influence data by affecting sampling from one area to another and from one time of the day to another. Under laboratory conditions temperatures of 110° - 115° F. were generally lethal to *Aedes* species. Pasture water seldom reaches this height, and, therefore, high temperatures apparently do not produce a limiting effect upon *Aedes* mosquito populations. However, temperatures below this lethal range do decrease growth rates and eventually exert a limiting effect. At certain low temperatures *Aedes* eggs fail to hatch if properly conditioned, and *Culex* species females go into semi-hibernation. Another example of a limited area study is the examination of the problem of larval food and its abundance. Bates (1949) and others conclude that under normal conditions food will not limit the abundance of species. Based upon general observations of fluctuations in *Aedes* larval abundance in pastures, it has been determined that larval food does not normally exert a limiting influence. Insect size also can be determined by the abundance of food. Overcrowding of larvae may decrease growth rates, larval size, longevity, and fecundity. If overcrowding is extreme in the early instars, failure to attain a certain size will prevent pupation and result in the death of a portion of the population. However, this seldom is the case in nature. It should be noted that a study of larval food habits may open avenues of control through the destruction of food or by interfering with methods of feeding.

Complex temperature moisture interrelationship can be demonstrated. The egg stage in *Aedes* species shows periods of arrested development or delayed physiogenesis. As mentioned before, *Aedes* eggs fail to hatch during the winter although flooded frequently. Apparently conditioning factors of moisture and temperature relationships initiate and define the length of this period. Based upon recent work on egg hatching stimulii it has been suggested that a quiescent or dormant condition in *Aedes* eggs may occur during the summer which may be broken by a combination of factors (unknown) to produce sudden increases or decreases in summer populations of *Aedes* mosquitoes.

The basic data regarding mosquito populations produced in a single irrigated pasture may apply to fields of the same general type. Fields of different types must require some modification in the application of data. Examples of "single pasture" ecology studies of interrelationships can be cited, based upon previous work. Examples are: the influence of irrigation cycles upon size of resultant broods of mosquitoes; species composition of pastures and the influence of pasture deterioration upon species composition; the relationship between *Culex* and *Aedes* mosquitoes and their control (Thurman, 1950 and Husbands, et. al., 1951, 1952, 1953). Implied in this work is the relationship between temperature (weather) and the initiation of insecticidal control in individual pastures.

Examples of comparisons between several pastures in the same general area can be cited from the past season's work in Merced. In this study, irrigation efficiency was related to mosquito production in three pastures. Measurements indicated that in general the increase and decrease in irrigation efficiency resulted in a proportional decrease and increase in mosquito production. Careful analysis of these results and the design of the experimental methods depended to a great degree upon an understanding of the previously mentioned and other interrelationships.

Area-wide (counties or abatement area) problems in ecology that influence mosquito production are those that involve adult population build-up, the speed of control activities, etc. Light trap or pants leg count sampling reveals to some degree the local situation. Yet to be applied to such areas is the theory of measuring egg densities in irrigated fields as a means of determining the efficiency of control. Methods of sampling could include the soil sampling techniques developed by the irrigated pasture study (Husbands, 1952) or by the construction of "egg traps," or especially designed small field plots to be flooded regularly and evaluated for larval production without adult production. Another interesting interrelationship that can be considered as an area-wide problem is the one involving the rate of larval development in fields and the initiation of insecticidal control in the spring and early summer. The ultimate application of this knowledge requires that two factors be known: one, the mean daily temperature; and, two, the *maximum* height and duration that water will remain on each individual field in the early summer. A few measurements of water levels in individual pastures can classify fields into various categories so that control operations can be initiated when rising temperatures show that larvae will successfully emerge as adults from fields of a specific category. The use of this idea remains to be applied and proven as practical.

State-wide pasture ecology is still very much in a theoretical stage. However, the history of the development of irrigated areas provides clues to the successional changes in species of mosquitoes encountered in the valley. River bottom swamp and inundation species of mosquitoes were replaced in abundance by floodwater species adapted to frequent irrigation floodings. *Aedes dorsalis,* which was prevalent up to 1937 in irrigated areas, was replaced in prevalence by *Aedes nigromaculis* in most areas. However, it is still questionable if one species displaced another. Food and space are apparently not limiting factors for larval development. The two species live together in most pastures; occasionally one species is more abundant than the other. Since we have no exact data about the densities of *A. dorsalis* previous to 1937, it is very possible that *A. dorsalis* is still as prevalent but is generally outnumbered in many areas by comparison to *A. nigromaculis.* We should define the term "replaced" or use it only with a great deal of caution.

The historical development of irrigation in California can be used as an example of changing state-wide interrelationships. In the Central Valley of California irrigated areas were developed adjacent to dependable sources of surface water. Parallel with this development was the formation of irrigation districts, which by 1930 irrigated 37.8 per cent of the 4,731,632 acres under irrigation in California. By 1953 this irrigated acreage had increased to 6,618,595 acres, primarily through the development of the Central Valley Project.

Maps of irrigated acreage in California show that prior to 1935 irrigated areas did not form a continuous chain along river bottoms in the Central Valley. Many stretches of land between irrigated areas were dry-farmed. Today, these barriers are mostly removed. The future development of water in the state will provide greater opportunities for the invasion of new species of mosquitoes. *A. nigromaculis* and its relatively recent invasion of the valley should be all the proof that is needed that it can happen again. As previously mentioned, basic to this is the changing ecological interrelationship providing favorable niches for the distribution and abundance of species of mosquitoes. Each species poses new problems for which we must be prepared.

The development of "ecological practicality" or mosquito control from investigations will be determined by future developments, primarily economic and agricultural, which in turn will be influenced directly and indirectly by information obtained from mosquito studies.

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RICE FIELD MOSQUITO ECOLOGY

Richard W. Gerhardt, *Entomologist*
Cooperative California Mosquito Control Association-Bureau of Vector Control Rice Field Ecology Study

The rice field mosquito problem has been with us for a long time. Far too many people have come to accept mosquitoes as an inevitable product of rice culture. The California Mosquito Control Association and the California State Department of Public Health, Bureau of Vector Control, fortunately, do not take this view. These organizations established the Rice Field Mosquito Ecology Project in 1950 in a concrete effort to study and devise possible solutions to this complex mosquito problem.

Rice fields, as places of mosquito production, have been studied for many years. Entomologists and public health workers of earlier days soon discovered that not all rice fields produced mosquitoes. They found that some of the fields produced virtually none.

Here was an intriguing ecological problem. If the reasons for a lack of mosquitoes in these fields could be understood, such might offer a means of reducing mosquito populations in other rice fields.

Many theories have been offered as explanations for this observation. None of these theories have been subjected to scientific testing by experimental methods; therefore, all stand in need of verification.

The objectives of the Rice Field Project have been: to test some of these ideas, eliminating those which seemed unprofitable while exploring more fully the more promising avenues of research; and to investigate new leads uncovered in the orderly study of the various aspects of rice field ecology. The following examples will serve to illustrate:

CHEMICAL PROBLEMS:

It has been advanced that if vigorous springtime control were exercised adjacent to rice-growing areas, the mosquito population could be sufficiently reduced to avoid troublesome numbers of mosquitoes originating from the rice fields themselves.

During the spring months of 1952 the personnel of the Rice Field Mosquito Ecology Project set out to test this hypothesis.

An isolated rice field was chosen and a 25 square mile area surrounding the field was larvicided with great care. The job was thoroughly done and no larvae could be found in the larvicided area after the treatment. However, larvae appeared in the natural field pools within 12-14 days after treatment. The area then was larvicided again. The results of the second application were again excellent.

During this second treatment the area surrounding the rice field was flooded and thus was available to mosquitoes for oviposition.

Within two weeks after the second treatment both the rice field and the naturally occuring larval habitats nearby contained abundant larvae.

It would seem that such a program, conducted on a limited basis, is not sufficient, in itself, to control rice field mosquitoes.

On the contrary, some evidence recently has been accumulated which suggests that the use of insecticides in and near rice fields may so reduce the population of natural predators that the mosquitoes, which inevitably penetrate the area, have a degree of survival exceeding that which might be considered normal.

CULTURAL PRACTICES:

It has been advanced that cultural practices of rice farming may have a profound effect on mosquitoes originating from rice fields. The presence of unnecessary seepage and waste water, in particular, constitute problems. We hardly need to provide experimental evidence to prove this point. The importance of sound engineering in laying out checks with proper grade as a means of rendering fields less productive of mosquitoes is certainly not subject to question.

Some other agricultural practices may possibly affect the numbers of mosquitoes arising from the rice field proper. For example, we are not sure of the possible effects on mosquitoes of different fertilizers or cover crops employed in rice culture.

We have some information indicating that clean cultural practices, which reduce weed growth to a minimum, are of some help.

LIMNOLOGICAL ASPECTS:

A study of the rice field aquatic habitat was undertaken during 1953. The study is still continuing.

An effort was made to relate the numbers of mosquitoes produced in the study plots to a variety of physical, chemical, and biological factors. No physio-chemical factor, such as dissolved gasses, pH, inorganic solids, temperature, depth of water, or basin conformation, was found to vary sufficiently to affect the mosquito population *directly*.

On the other hand, the biota of the rice field has been observed to correspond, in general, to the relative density of aquatic stages of mosquitoes. A diversified and abundant planktonic biota went hand in hand with high mosquito occurrence, while a poorly developed or restricted biota was associated with few mosquitoes.

ALGAL TRANSPLANT STUDIES:

Dr. W. C. Purdy in 1919 found a rice field in the Nelson, Butte County, California area which produced no mosquitoes. He attributed this lack of mosquitoes to the presence of a dominant growth of blue-green algae within the rice field.

In testing Dr. Purdy's hypothesis we have cultured a few species of algae and have subjected mosquito larvae to the filtrates of these cultures. Some circumstantial evidence exists which seems to indicate that some metabolite of these algae may be toxic to mosquito larvae.

Some field testing has been done with these species of blue-green algae. Attempts have been made to transplant these algae from their natural environments to other rice fields. Five successful transplants have been made. The effect of the transplanted algae on the mosquito populations of the fields has been difficult to measure, but the data gathered are very promising. We need to study the relationships of the abundances of these algae to soil types, pH, water quality, and numerous other ecological factors.

FUTURE NEEDS:

The field of biological mosquito control, with emphasis on predators, parasites, and biological antagonists, has hardly been scratched. Continued investigation into the influence of antibiotic microbiota is strongly indicated. Not only must we continue to study blue-green algae as mosquito deterrents, we also must search out and learn about other plant and animal life and their by-product which conceivably may contribute to mosquito control.

Recent studies indicate that natural predators, both fish and invertebrates, have not been duly considered and utilized by mosquito control workers. Future work in this field is considered essential in order to ascertain the possible role of predators in the biological control of mosquitoes.

The long range objectives of the project will be to continue to search for and develop promising means of controlling rice field mosquitoes. Immediate activity will concentrate upon projects currently under way. New studies will be developed as rapidly as time and available personnel permit.

California now has approximately a half million acres of rice, with insecticides being the only basis for limiting the mosquito production from this vast area. Creditable progress has been made thus far in expanding the knowledge regarding possibly better and more economical methods through utilization of the ecological approach. It can be safely predicted that with adequate support gains will continue to be made in the future on this sound scientific basis.

SIXTH SESSION *(Concurrent)*

1:30 P.M., WEDNESDAY, JANUARY 26, 1955

ST. LOUIS ROOM, HOTEL STATLER

Dr. Don M. Rees, University of Utah, Salt Lake City, Utah, presided over this session for the presentation of submitted papers.

GRANULAR INSECTICIDE CARRIERS USED IN UTAH IN MOSQUITO ABATEMENT OPERATIONS

JAY E. GRAHAM AND DON M. REES
Salt Lake City, Utah

Granular materials have been in use for several years as carriers for mosquito larvicides. The use of these granular larvicides in the United States prior to 1954 was adequately summarized last year at the New Jersey meetings by R. L. Vannote and G. E. Washburn.

Rees, Edmunds, and Nielsen (1953) reported the advantages of using granular insecticides for treating small mosquito producing water by hand application at the time of inspection. These advantages were further confirmed by the continued use of granular larvicides in Utah during 1954.

Granular formulations first were used in Utah for mosquito larviciding in 1951 when the Salt Lake City Mosquito Abatement District received, through the efforts of Robert L. Vannote, 500 pounds of granulated tobacco stems impregnated with 10% DDT, from the Tobacco By-Products and Chemical Corporation of Richmond, Virginia. Since that time the Salt Lake City, South Salt Lake County, and the Weber County Mosquito Abatement Districts have used other granular carriers on an experimental basis in both hand and airplane applications.

In an attempt to obtain the most suitable granular larviciding material for hand application, a number of granular carriers were investigated during 1954. The granules used were impregnated with different concentrations of aldrin, dieldrin, and heptachlor. This investigation was not exhaustive but some of the results obtained seemed to be significant and are herein presented for consideration.

The first granules used in 1954 were bentonite of 30-60 mesh containing 2½% heptachlor which had been stored during the winter. These granules were not lethal when applied to first instar larvae of *Aedes dorsalis* but appeared to act as a growth inhibitor on the larvae. The supply of these granules was exhausted before this could be further investigated.

Bentonite granules containing 5% dieldrin and 5% urea as a deactivator were used as a pre-hatch treatment in several areas. The granules were applied at the rate of approximately 10 pounds per acre. When applied to areas that were intermittently flooded during the year, this material apparently was effective for the entire season, but when applied to an area of permanent water, it was effective for less than two months.

Throughout the summer several granular formulations were tested in the field by hand application using regular control procedures. The carriers used were granulated tobacco stems, bentonite, attapulgus, vermiculite, celite, and panacalite. At the dosages normally used, all of these granules produced satisfactory results, but the granules were not equal in all respects. An attempt was made to evaluate the carriers on the basis of the following factors: effective coverage, penetration of vegetation, visibility of dispersed granules, acceptability for handling, the need for deactivators, and the cost per acre of the material used. Included in effective coverage were the distance the granuls were dispersed when thrown and the manner in which they spread over the area treated. Acceptability for handlang included the ease with which the granules can be transported in the field by the inspector and any unpleasantness experienced when applied by hand. The following is a chart showing the results of this evaluation:

From the above scoring, panacalite granules are apparently the most satisfactory of those tested. As prepared for mosquito larviciding panacalite is a white floating granule readily visible when applied. It is light in weight, 8 lbs. per cubic foot; it absorbs some moisture without clumping; and it is not offensive for handling in the field. It also was found that water can be added to panacalite granules in the field to make a heavier granule for casting into the wind when necessary. In addition, one pound of panacalite granules can be used to treat an area eight times the size of that which can be effectively treated by one pound of bentonite.

Mr. Lewis E. Fronk, manager of the Weber County Mosquito Abatement District, used panacalite granules in airplane applications during 1954, but the results were not uniform. According to Mr. Fronk this was principally due to inadequate equipment on the airplane used in applying the granules. Mr. Fronk is of the opinion that panacalite granules are effective carriers when properly formulated and applied.

SUMMARY AND CONCLUSIONS

Granular formulations are the most satisfactory type of larvicide that have been used in Utah to treat mosquito producing waters by hand application at the time of inspection.

Granular formulations are very effective when used under conditions where the larvicide must pass through dense vegetation to arrive on the surface of the water.

All of the materials investigated as granular carriers of larvicides were effective as carriers, but panacalite was

COMPARISON OF GRANULAR CARRIERS

Granules	*Effective Coverage*	*Penetration of Vegetation*	*Visibility of Applied Granules*	*Acceptability For Handling*	*Deactivator Required*	*Cost Per Acre**
TOBACCO STEMS 30 - 50 MESH	GOOD	GOOD	POOR	POOR	NO	?
BENTONITE 36 - 60 MESH	GOOD	GOOD	GOOD	GOOD	YES	$1.00 - 2.00
ATTAPULGUS 20 - 40 MESH	GOOD	GOOD	FAIR	GOOD	YES	$1.00 - 2.00
VERMICULITE 30 - 60 MESH	FAIR	GOOD	FAIR	GOOD	YES	?
CELITE 30 - 60 MESH	FAIR	GOOD	FAIR	GOOD	YES	?
PANACALITE APPROXIMATELY 60 MESH	GOOD	GOOD	GOOD	GOOD	NO	$0.25 - 0.40

*COST IS BASED ON PRICE OF GRANULES DELIVERED AT SALT LAKE CITY superior to the others as determined by the characteristics considered in making the comparison and the conditions under which the granules were used.

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EDITOR'S NOTE: The following presentations given on this session were pictorial in nature and papers were not submitted for publication:

"Killing mosquitoes with a camera" *by* EDGAR A. SMITH, *Santa Clara County Health Department, San Jose, California.*

"Merced County MAD'S experiences with 3-way radio as a mosquito control tool" *by* JOHN O. STIVERS, *Merced County Mosquito Abatement District, Merced, California.*

"OPERATION MERCY"[1] (SUMMARY)

DONALD R. JOHNSON[2]

United States aid in the form of health technicians and tons of medical supplies were airlifted within hours after receiving an appeal for help to East Bengal Province of Pakistan in August 1954. Unprecedented floods in this thickly populated area of the world had inundated 15,000 square miles of land where outbreaks of malaria and cholera were feared following the flood. Six U. S. Public Health Service experts and 168 U. S. Army preventive medicine personnel were flown to the stricken area. U. S. Air Force provided Globemasters and Flying Boxcars for the airlift in this dramatic operation.

Spraying of refugee centers in the flooded area was made possible by the 10 tons of dieldrin 50% wettable powder and 250 compression sprayers which were among the tons of supplies procured by the U. S. Foreign Operations Administration. More than 30,000,000 anti-malaria tablets were also provided. No epidemics of malaria, cholera, or other diseases were reported following the recession of the flood. Expanded malaria control activities as part of the permanent program for the Province were planned with the help of the Public Health Service relief team. Eventual protection from malaria for the entire 42,000,000 population of East Bengal is anticipated.

[1]Summary of address presented at 11th Annual Meeting of the American Mosquito Control Association on January 26, 1955, in Los Angeles, California.

[2]Entomologist, Division of International Health, Public Health Service, U. S. Department of Health, Education, and Welfare, Washington 25, D.C.

THE 1954 CONTROL TREATMENT OF THE CLEAR LAKE GNAT *CHAOBORUS ASTICTOPUS* D. & S., IN CLEAR LAKE, CALIFORNIA

HAROLD W. BRYDON, *Manager-Entomologist*
Lake County Mosquito Abatement District

Clear Lake, California, is infested with a small white gnat commonly called the Clear Lake Gnat, *(Chaoborus astictopus)*. This gnat, as an adult, is a non-biting insect; but even so, because of its tremendous, attraction to lights, and ability to pass through most window screens, it is considered to be an obnoxious pest that has had an adverse affect upon the large resort business of Lake County. It does, when its numbers become too great, create a public health problem by imparting asmatic conditions and eye irritations to susceptible individuals.

It is because of this insect, during the several years preceding the fall of 1949, that Dr. A. W. Lindquist, A. R. Roth, and several other individuals spent a great deal of time, money, and effort in studying this gnat and developing a method of controlling it without creating too many deleterious effects upon the other aquatic organisms of Clear Lake, particularly so where the fish population was concerned. As a result of these studies, a method of control was evolved; and during September of 1949 the 62.73 square miles of Clear Lake was treated with a 14,000 gallon formulation of D.D.D. This treatment was so successful that Clear Lake was almost completely free of the pestiferous gnat for approximately two years.

On July 30, 1951, the larval form of the Clear Lake Gnat was collected by means of a night plankton tow, for the first time since the treatment. From that date on, the population steadily increasing during the summer months until it reached a level during the summer of 1954 when it became necessary to exercise a second control treatment.

It is the 1954 treatment of Clear Lake with which this paper concerns itself.

Clear Lake is about 8½ miles wide at its greatest width and is a little over 19 miles in length. The Lake is composed of three more or less distinct sections with the upper section being the largest. In the plan of application it was decided to divide the Lake off into sectors very similar in pattern to that employed during the 1949 treatment. Therefore, the upper section was divided into six sectors; the southeasterly section was divided into two sectors; the easterly section was taken in its entirety as one sector. The sectors in the upper half of Clear Lake were laid out one mile apart in width and extended to within one half mile of the shore. The courses that the surface craft were to follow were laid out at about 700 feet apart within each sector.

A local pile driver was engaged to mark each sector by means of pilings topped with large 5 x 5 x 4 marine plywood boxes painted with wide alternating horizontal stripes of white and international orange. The pilings were placed at one mile intervals along the boundaries of each sector except at the extremities of the sectors, and there the pilings were driven one half mile from shore. This blocked the Lake off into approximately one mile squares.

Local boat and barge owners were contacted with the result that five local outfits were available for the treatment. In considering the time element involved to cover the number of course miles to be traveled in completing the upper half of Clear Lake in one day, it was necessary to bring in three self-propelled barges from outside of the County. This gave eight outfits to complete the first day's application with a good safety margin of time, should one or more outfits break down.

In ordering the insecticide, it was felt that the same formulation as was used in 1949 should again be employed. However, since some difficulty had been experienced with recent field and laboratory tests in obtaining adequate kills at the same concentration as was used in 1949 (1 part of active insecticide to 70 million parts of water) a stronger concentration (1 part of active insecticide to 50 million parts of water) was planned on. Therefore, 20,000 gallons of insecticide was ordered in fifty gallon drums according to the following specifications: 30 grams D.D.D., Technical Grade (Rhothane D-3), 10 cc Triton X-100, emulsifying agent (by volume), and 72 cc Xylene (crude product), with a Specific Gravity of One. When the insecticide was delivered, it was stored at two loading locations on opposite sides of the Lake.

An injection of preemulsified insecticide was felt to be the most desirable means of introducing the insecticide into Clear Lake. The method of preemulsifying was accomplished by placing a two inch gasoline driven pump on each barge. A two inch water intake hose was fastened over the side of the barge with the outlet hose fastened over the bow or the stern of each barge. An aspirator system, composed of pipe fittings and valves, was connected between the water intake hose and the pump.

In the aspirator systems a brass gas cock valve was used as a volume flow control valve for the insecticide. Each of these valves was marked with a setting for the valve handle. The settings were determined for each individual pump and barge combination from calculations derived from the speed of the barge, under loaded conditions, and from the number of drums the barge would be expected to disperse over a given area within a given length of time. In some cases it was necessary to have two settings on a valve for flow regulation over varying depths of water. The control valve connected directly to the water intake through a Durham "Y" fitting. Beyond the valve a "T" was placed with a garden faucet valve at each end of the two arms of the "T". These garden valves were called "shut-off valves". A ¾ inch 25 foot clear plastic garden hose was connected to each garden valve. The far end of the hose was connected to a 4 foot length of pipe that was inserted into the drum of insecticide. Under operating conditions the control valve would be set at its predetermined setting and one garden valve opened. When the drum that was being used became empty, the valve would be closed and the second "shut off" valve opened. The hose leading to the first drum would then be moved to the next drum and thereby a continuous accurate flow of insecticide could be maintained by each barge throughout the operation.

In obtaining a successful treatment of a body of water the size of Clear Lake there are many physical and chemical aspects that must be considered. Any one of several different factors could greatly hamper such an undertaking, should a factor or factors be in an adverse state. A period of time between September 20 and October 15 was selected as the period most likely to have many of the factors favoring the treatment.

Among the factors to be considered was the need for a breeze of sufficient strength that would produce subsurface water currents which would thoroughly and evenly distribute the insecticide within a short period of time. Also, a breeze would build up the oxygen content of the water and provide a greater margin of safety to the fish population. A good wind blew on September 20 and 21 and created the type of water currents necessary to success. These water currents were of sufficient strength to last for several days. Daily contact with the U. S. Weather Bureau indicated that another period of windy days would arrive about September 26 or 27. The oxygen content readings on September 24 were high, with 7.9 ppm at the lake surface and 7.1 ppm at the bottom.

All calculations for the insecticide distribution were based upon a level that would exist about October 1st. This exact level existed on September 24. A pH of less than 8.1 to 8.2 was desirable from the standpoint of detrimental effects upon the D.D.D. under too alkaline conditions. September 24 pH readings were 8.0 at the surface and 7.9 at the bottom of the Lake.

The average temperature of the Lake was 68° F. on September 24. At this temperature there is still a high percentage of nocturnal vertical migration on the part of the larvae. The larvae are quite negatively phototropic and spend the daylight hours in the mud at the bottom of the Lake, coming out into the water during the night to feed. It is during this feeding period that the insecticide is effective. Also at 68° F. the adult gnats will not last for long, the larval form is the overwintering stage, and the possible repopulation sources from small outlying lakes and ponds could be treated during the winter months. Also at lower temperatures the oxygen content is higher than during the summer months when an average Lake temperature of 80° F. is not uncommon.

The Lake had become quite turbid during the windy days; however, it had cleared considerably by September 24, and the suspected danger from the colloidal properties of the bottom mud in reducing the amount of effective insecticide had lessened.

During the dark of the moon a greater percentage of the larvae tend to migrate out of the mud than during the time of a full moon. During the last of September there was little or no moonlight.

The boats and barges had been ready since September 20; the crews had been sufficiently briefed on the procedures and had been given practice runs. Therefore, since the various chemical and physical factors were in favor of a successful treatment, the equipment and crews ready, the application was begun at dawn on September 25. The first day's application was completed by mid afternoon, and the barges for the second day's operation were loaded late in the afternoon of the first day. The second day's application was completed by early afternoon, and the barges had not yet returned to their base locations before a breeze, as forecasted by the U. S. Weather Bureau, had started. This breeze continued on through the following day and undobutedly aided in the distribution of the insecticide and in maintaining a high oxygen content in the water.

By the end of the second day's application a total of 20,000 gallons of insecticide had been injected into Clear Lake at a concentration of one part of insecticide to 50 million parts of water and at a cost of $57,000.

Prior to the treatment of Clear Lake, representative mud samples of the Lake bottom were taken by means of an Eckman Dredge. The September 8 mud sample survey was the last complete survey made on the larval population before the treatment. The restults of this survey showed that an average population level of 10 larvae per square foot existed in the Lake. Spot checks made three days before treatment indicated a very high population of gnat larvae in various locations, and it is on the basis of these spot checks that the first results of the treatment are esimated at a 60% kill on he third day following treatment. All of the following percentages are based upon the September 8 reading. Sixth day after treatment a 99.906% kill existed. On the thirteenth and twentieth day after treatment a 99.995% kill had been obtained, and on the fortieth day after treatment a 100% kill had been obtained, so far as mud samples were concerned.

On the thirty-first day after treatment a series of night plankton tows were taken. An estimated 25,000 cubic feet of water was sieved, and three larvae were collected. Had the Lake not been treated a conservative estimate would be that at least 2,500 gnat larvae would have been collected instead of three.

Each morning for several days following the treatment the surface of Clear Lake was covered with small, almost transparent forms of dead and dying larvae, as well as partially and fully emerged adult gnats that had been killed during the previous night. Wave and wind action tended to pile the dead and decaying larvae up on the shore line where they attracted many flies. Various species of fish were observed by the thousands swimming near the surface and scooping the dead larvae into their mouths. The insecticide apparently did not harm the fish population for no dead fish were observed in such numbers that could not be accounted for by the ordinary fish mortality that occurs almost continuously. Immediately following the treatment of Clear Lake a program of treating the lakes, ponds, and sloughs of the outlying area was started in an attempt to postpone the third Lake treatment. Even though the larval form of the Clear Lake Gnat may not now be found in Clear Lake through the sampling of the bottom mud and through plankton tows, it is realized that some are still there, and because of this small white gnat's ability to increase its numbers so rapidly (one female gnat may lay as many as 300 eggs) it is but a question of time before Clear Lake will again be treated.

HYDRAULIC PIPELINE DREDGES FOR MOSQUITO CONTROL

Charles W. Blaney
Ellicott Machine Corporation
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Hydraulic pipeline dredges are appearing in increasing numbers throughout this country and in many nations throughout the world. They are being used on a variety of projects from harbor maintenance to digging canals. Their foremost use, however, is in obtaining fill materials. The reason for this increase in number is that materials can be moved from one location to another by hydraulic dredging, cheaper and quicker, than by any other known method.

If your district is faced with the problem of controlling mosquito breeding in swamps and marshes, and there is an ample quantity of underwater fill materials available, there is no doubt that a hydraulic pipeline dredge will help you.

I will now tell you of several instances of how others have employed dredging equipment to combat mosquitoes.

In the City of Barranquilla, Colombia, there was for many years a section known as the "ZONA NEGRA" or "BLACK ZONE." This area, parallel to the Magdalena River, had been polluted by open sewers and every year flood waters created mosquito breeding swamps. Since the "BLACK ZONE" was inhabited by approximately 60,000 people, there was the constant threat of a malaria epidemic.

A thorough study of the problem by City officials and the Inter-American Public Health Service brought out two conclusions. The problem of Malaria could be somewhat controlled through the use of insecticides, or the entire area could be filled, doing away with the swamps and open sewers and thereby ending the mosquito breeding problem in the "ZONE."

After investigating various methods of obtaining fill materials, it was found that the river could be deepened, and the materials obtained from the river used for fill. It was also realized that new waterways could be created.

With this thought in mind, the authorities contacted the Ellicott Machine Corporation and one of its engineers visited the site. A 12-inch hydraulic pipeline dredge was recommended and the authorities concurred. The dredges "ANOPHELES" was purchased for delivery in the summer of 1947. Upon arrival, it worked in conjunction with the dredge "GENERAL EDUARDO SANTOS," also constructed by Ellicott; and by May, 1950, over one million cubic yards of fill had been pumped in.

As a result, the "ZONA NEGRA" was made available for industrial development which has benefitted the city economically; and by eradicating a mosquito breeding area, dividends in better health for its citizens has resulted.

In the Upper Passaic Valley, New Jersey, Bob Vannote and the Morris and Essex Mosquito Extermination Commissions fought for years to overcome the mosquito problem. The Passaic River flowing through the 26-mile distance from Chatham to Little Falls could not handle the rain waters which drained from the hills along its banks.

Because the river could not drain off these waters, they created ideal breeding areas, much to the discomfort of more than a million people living in an area extending six to eight miles in all directions.

Prior to 1938, attempts at mosquito control through chemicals had proven to be only temporarily effective. Here, also, it was realized that only through the use of mechanical methods could the entire area be reclaimed and floods controlled.

The first piece of equipment, a drag line, proved to be ineffective because the trees bordering the river interfered with its effectiveness. In seven months, the drag line could remove only an average of 3,000 cubic yards of materials per month. Next, a barge-mounted one-half yard clamshell was employed, but this too failed to solve the problem because of its small output of 180 cubic yards per day.

Bob Vannote then contacted Ellicott; and, after a study of the problem, a 10-inch hydraulic pipeline dredge was recommended, and the dredge "BELLE OF THE PASSAIC" was put to work in 1939.

During its use, the dredge removed an average of 20,000 cubic yards of material per month and distributed them throughout the low-lying areas. The river was widened up to 90 feet and the depth increased by 4 feet, as required.

This improvement of the river bed by means of hydraulic pipeline dredging has made possible the rapid draining of areas bordering it. It also has meant that mosquito breeding can now be controlled, thus benefitting the populace, which has almost doubled in number.

As you no doubt are aware, the Florida State Legislature voted in 1953 to make available to the Mosquito Control Districts throughout the state additional sums amounting to 75% of each district's mosquito control allotment. This sum is to be used for permanent control methods. As a result of this, Brevard and Volusia Counties have purchased 10-inch hydraulic pipeline dredges. To give you the experiences of these dredges, I refer you to the paper entitled "HYDRAULIC FILLING FOR PERMANENT CONTROL OF ARTHROPOD BREEDING AREAS IN BREVARD AND VOLUSIA COUNTIES," which was presented by Ernest A. Philen, Sanitary Engineer, Florida State Board of Health, at the Florida Anti-Mosquito Association Convention at Naples, Florida, on April 27, 1954. These papers are available at the Ellicott Machine Corporation display here, or by contacting the company direct at 1611 Bush Street, Baltimore 30, Maryland.

These examples show what has been done and is being done by mosquito fighters in this section of the world. In the Far East, the Republic of Indonesia has a fleet of 12 dredges, ranging in sizes from 8-inches to 24-inches, working on mosquito control and other sanitary projects.

Should your district be faced with a problem similar to the above, Ellicott with its complete facilities, welcomes the opportunity to assist you.

EFFECTIVENESS OF SOME ORGANIC PHOSPHORUS AND OTHER INSECTICIDES AS AEROSOLS AGAINST MOSQUITOES

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Entomology Research Branch, Agr. Res. Serv., U. S. Department of Agriculture

AND

Richard F. Peters
Bureau of Vector Control, California Department of Public Health[1]

An unusually large population of *Culex tarsalis* Coq. developed in California in 1952. This was followed by the largest number of human encephalitis cases that has been recorded in the State, according to Halverson *et al.* (1953). The possibility that such outbreaks may occur again makes it important to have effective methods available for controlling both the larvae and the adults of this mosquito.

The high level of resistance to chlorinated hydrocarbon insecticides present in both *tarsalis* and *Aedes nigromaculis* (Lud.) (Gjullin and Peters, 1952) has made it necessary for several mosquito abatement districts in the San Joaquin Valley to use organic phosphorus larvicides in recent years. Poor results also have been obtained with chlorinated hydrocarbon aerosols for the control of adults in these areas. Aerosols are used against adult mosquitoes in many abatement districts in California when larvicidal sprays fail or large numbers of adults emerge for other reasons, but the real need for an effective aerosol in this area is for the control of *tarsalis* adults over rather large areas in the event of an encephalitis outbreak.

Laboratory aerosol tests with several organic phosphorus insecticides showed that malathion and chlorthion were among the most effective of these materials and that they caused much higher kills of resistant *tarsalis* and *nigromaculis* than several chlorinated hydrocarbon insecticides (Gjullin, 1953). In 1954 field tests with malathion and chlorthion were made in the vicinity of Merced, California. The possible toxic hazard of these aerosols to the operators of the machines and to other personnel engaged in the study was investigated by the Bureau of Adult Health of the California Department of Public Health while the tests were in progress.

The aerosols were produced with Husman and Bes-Kil machines, which were set to deliver 20 and 40 gallons per hour, respectively. Applications of 12 or 24 gallons per mile were made by adjusting the speed of the jeep used to carry the Husman unit and to pull the Bes-Kil. The Bes-Kil was a standard commercial unit producing a particle size of approximately 55 microns mass median diameter. The Husman machine was a pneumatic sprayer (Husman, 1953) adjusted to produce droplets having a diameter of approximately 44 microns. The Bes-Kil was operated at approximately 475° F. and the Husman at air temperature.

The purity of the technical malathion was 99 and of chlorthion 86 percent. These products were tested in diesel oil on a weight-to-volume basis. No trouble was encountered with the solubility of malathion in diesel oil, but a small amount of chlorthion was in suspension. The DDT and BHC solutions were prepared on a volume-to-volume basis, the DDT from a 30-percent concentrate and the BHC from technical BHC to 11-percent gamma content.

The tests were made in grass pastures that were irrigated about once a week and produced huge numbers of *nigromaculis.* Counts of 500 or more on the front of one trouser leg were not uncommon at dusk when mosquito activity was at its height. In pastures where newly emerged adults were particularly numerous, cattle were observed to stop feeding mill around in a compact group at this time of the evening.

On test plots 200 yards long a team of three men made landing-rate counts on the trouser legs before and after the aerosol was dispersed. Another man made similar counts at the same times in an untreated portion of the pasture, and the test-plot counts were adjusted on the basis of these counts. The counts in the test area were made in three lines, approximately 35 yards apart, perpendicular to the line of aerosol dispersal and near its center. Counts were made 50, 100, 200, 300, and 400 yards from this line, and locations were marked with stakes so that pre- and post-counts could be made in the same place.

The aerosols were usually applied after sundown and either before sunrise or shortly thereafter. Wind speeds ranged from 1 to 9 miles per hour. Pre-counts were usually made just before each application. However, the weather was unusually cool in August and September and mosquitoes did not fly until just before sunrise or later; therefore, to avoid air lapse or changes in wind direction before aerosols could be applied, some pre-counts were made the previous evening.

Post-treatment counts for the evening tests were made about 9:30 a.m. the following morning and for the morning tests at 10 a.m. or later. These differences in time after treatment were undesirable, but weather conditions prevented any other plan. However, there was little difference in the counts made 13 hours after the evening tests and 3 hours before the morning tests. Results of the tests are given in table 1.

Five percent malathion or chlorthion in diesel oil gave over 90 percent reduction of mosquitoes for 100 yards and from 70 to 90 percent up to 400 yards. These materials also were highly effective for 100 yards at 2.5 percent, but reductions at greater distances were slightly less than those obtained with the 5 percent strength. Five percent

[1]Employees of the Bureau of Vector Control and James Lanier of the Chemagro Corporation made the landing-rate counts and operated the aerosol equipment during these tests.

Table 1.—Reduction of *Aedes nigromaculis* adults after dispersal of various insecticides in aerosols with Husman and Bes-Kil machines. Average of 3 or 4 tests.

Insecticide[1]	Concentration percent	Percent reduction in landing rate at 50 yards	100 yards	200 yards	300 yards	400 yards
		Husman				
Malathion	1	92	62	32	33	9
	2.5	94	90	62	63	65
	5	99	97	90	74	83
	5[2]	97	88	78	80	83
Chlorthion	2.5	94	87	85	70	70
	5	98	95	79	81	90
	5[3]	64	62	52	39	13
BHC (11% gamma)	5	90	81	78	68	78
DDT[4]	5	86	73	57	26	20
Pyrethrins	0.125	72	48	41	39	0
		Bes-Kil				
Malathion	5	100	93	95	94	95
Chlorthion[5]	5	99	100	99	97	96

[1]Diesel oil preparations were dispersed at 12 gallons per mile unless otherwise noted.
[2]24 gallons per mile.
[3]Xylene emulsion.
[4]Two tests.
[5]Single test.

chlorthion emulsion was approximately half as effective as 5 percent chlorthion in diesel oil. Pyrethrins at 0.125 percent was the least effective of the materials tested.

DDD and BHC gave good reductions of adult mosquitoes, but were less effective than malathion and chlorthion. The effectiveness *of DDT and BHC* was slightly greater than expected, which may have been due to a slightly lower resistance than was indicated in laboratory tests in 1953.

The relatively low decomposition temperature of malathion and chlorthion was not adversely affected by the 475° F. temperature of the Bes-Kil machine. Mosquito reduction in tests with this machine were somewhat higher than those obtained with the Husman machine.

SUMMARY

Malathion and chlorthion were tested against partially resistant adult mosquitoes in California to determine their value as aerosols. These materials caused over 80 percent reduction in the landing rate of *Aedes nigromaculis* 400 yards from the point of release when 5 percent in diesel oil was dispersed with a Husman machine. Both materials were more effective against this species than DDT or a BHC product containing 11 percent of gamma isomer. Pyrethrins at 0.125 percent was the least effective of the materials tested.

No breakdown of malathion or chlorthion was indicated in tests with these materials in a Bes-Kil aerosol machine operated at 475° F.

A clorthion-xylene-water emulsion was less effective as an aerosol than the chlorthion-diesel oil solution.

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SEVENTH SESSION

8:30 A.M., THURSDAY, JANUARY 27, 1955

SIERRA ROOM, HOTEL STATLER

Mr. Jack H. Kimball, Manager, Orange County Mosquito Abatement District, presided over this session on the California Operational Investigations and the reports arranged by the CMCA Regional Representatives.

IRRIGATED PASTURE STUDY — A REVIEW OF FACTORS INFLUENCING MOSQUITO PRODUCTION — WEATHER, PONDING AND IRRIGATION, AND SOIL MOISTURE[1]

Richard C. Husbands[2]

Factors influencing mosquito production have been under study for several consecutive seasons in a selected irrigated pasture in Madera County. Additional studies have been conducted in Stanislaus and Merced County. These studies have attempted to analyze factors and their relationship to mosquito production in order to establish new methods of control, to show the relationship between farm management and mosquito production, and to assist in the improvement of present mosquito control methods.

Based upon this work three primary factors will be discussed: one, weather; two, ponding and irrigation; and three, soil moisture. The inseparability and interaction of these factors and others are recognized. However, for complete analysis they must be examined separately to some extent. The three species of mosquitoes of major importance in pasture and reacting to these factors are: *Aedes nigromaculis* (Ludlow), *Aedes dorsalis* (Meigen), and *Culex tarsalis* Coquillett.

[1]A cooperative project conducted jointly by the California Mosquito Control Association, Inc., the Bureau of Vector Control, State Department of Public Health, and the Fresno Mosquito Abatement District.

[2]Ecologist, Project Leader, Central Valley Mosquito Ecology Study, California Mosquito Control Association.

WEATHER

Mosquito response, distribution, and abundance in terms of weather is the most difficult factor to analyze. Much of this difficulty arises from the fact that only the macroclimate has been recorded and microclimatic measurements have not been possible with the precision needed for their analysis. A minimum list of instruments needed for a study of the microclimate has been given by Smith (1953 and consists of an aspirating psychrometer, a black globe thermometer, an anemometer, and possibly an evaporimeter. However, in mosquito studies these should be modified to include an electrical moisture recorder, recording thermocouples, heat flow meter, radiometer, and a portable wide range photometer. Specific applications of these instruments would include the study of soil-surface, air-interface moisture problems in relation to *Aedes* eggs in the field, the microclimate available to ovipositing mosquitoes, surface temperatures that influence *Aedes* egg conditioning, the microclimate available to overwintering *Culex* species, etc.

To date, observations on weather have been confined to records obtained in a standard weather station located in the study area to give macro-changes in temperatures and humidities. Water temperatures have been recorded to a limited degree to show extreme fluctuations, stratification, and correlation with air temperatures. Table 1 illustrates the water temperature phenomenon in an irrigated study pasture near Turlock.

TABLE 1—*Records of Water Temperatures, Air Temperatures and Depths at Selected Stations for July 1, 1950, Schaub Pasture, Turlock, California.*

Station No.	*Air Temp.*	*Water Temp. Surf.*	*Bottom*	*Depth (inch)*	*Hour of Day*
E 23A	100	94		2.75	2:10
6A	101	104		3.20	1:45
19A	96	92		7.25	12:50 P.M.
17A	96	105		2.50	1:00 P.M.
13A	97	95	89	5.25	1:10 P.M.
W. ditch at 12A	98	94	85	9.50	1:15 P.M.
9A	98	96	79	6.75	1:20 P.M.
10A	98	102	100	4.50	1:30 P.M.
7A	98	101	100	4.50	1:35 P.M.
W. ditch at 6A	101	97	89	5.00	1:50 P.M.
E 12C	100	100	89	4.75	2:00 P.M.
Totals	882	882		49.90	
Last 7	690	685	621	40.15	
Av. Last 7	98.5	97.8	88.7	5.73	
Degrees F.					

Temperatures lethal to larvae (110° to 115° F.) were not attained in ponds. However, open areas or areas not containing vegetation were not preferred by larvae of *Aedes* species. Migration from top to bottom was influenced to a limited degree by increased variation in temperature from top to bottom. Food may be the factor affected and this phenomenon may not be directly related to temperature.

Air temperatures taken in a standard weather station show no direct correlation with fluctuations in *Aedes nigromaculis* populations for entire seasons. A correlation between population build-up and monthly average temperatures has been noted in some cases, Figure 1 and Table 2. During 1954 the months of May and June produced comparatively large *Aedes* and *Culex* populations in the special study pasture in Madera County. April, May, and June show above average mean temperatures, as compared to previous years under study. However, July, August, September, October, and November, 1954, were below normal and show a corresponding decrease in *Aedes* and *Culex* populations. In fact, the reduction was so great by comparison with previous years that it has been theorized that early season hatching of *Aedes* eggs may have reduced the potential eggs available for hatching during July through September. However, other factors, such as irrigation methods and soil moisture, may have contributed as much to this reduction in *Aedes* populations in the special study pasture. Since a general reduction in *Aedes* populations was reported to occur in many parts of the Central Valley after June, 1954, the process controlling this reduction may have resulted from a combination of unknown factors specifically influenced by weather.

TABLE 2.

Average Monthly Temperatures — Fresno Air Terminal
U.S. Department of Commerce Weather Bureau for 1951-1954

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
45.6	49.9	53.6	61.0	68.3	74.2	79.2	77.9	75.0	63.1	55.5	44.8	- 1951
45.2	49.9	50.1	60.9	69.6	69.1	81.7	79.1	75.5	68.2	52.6	46.9	- 1952
50.5	48.4	53.3	59.4	61.7	69.3	82.5	75.5	75.5	63.3	54.3	45.7	- 1953
46.7	49.6	51.8	62.9	69.7	71.7	81.4	74.5	71.2	63.7	52.4	43.8	- 1954

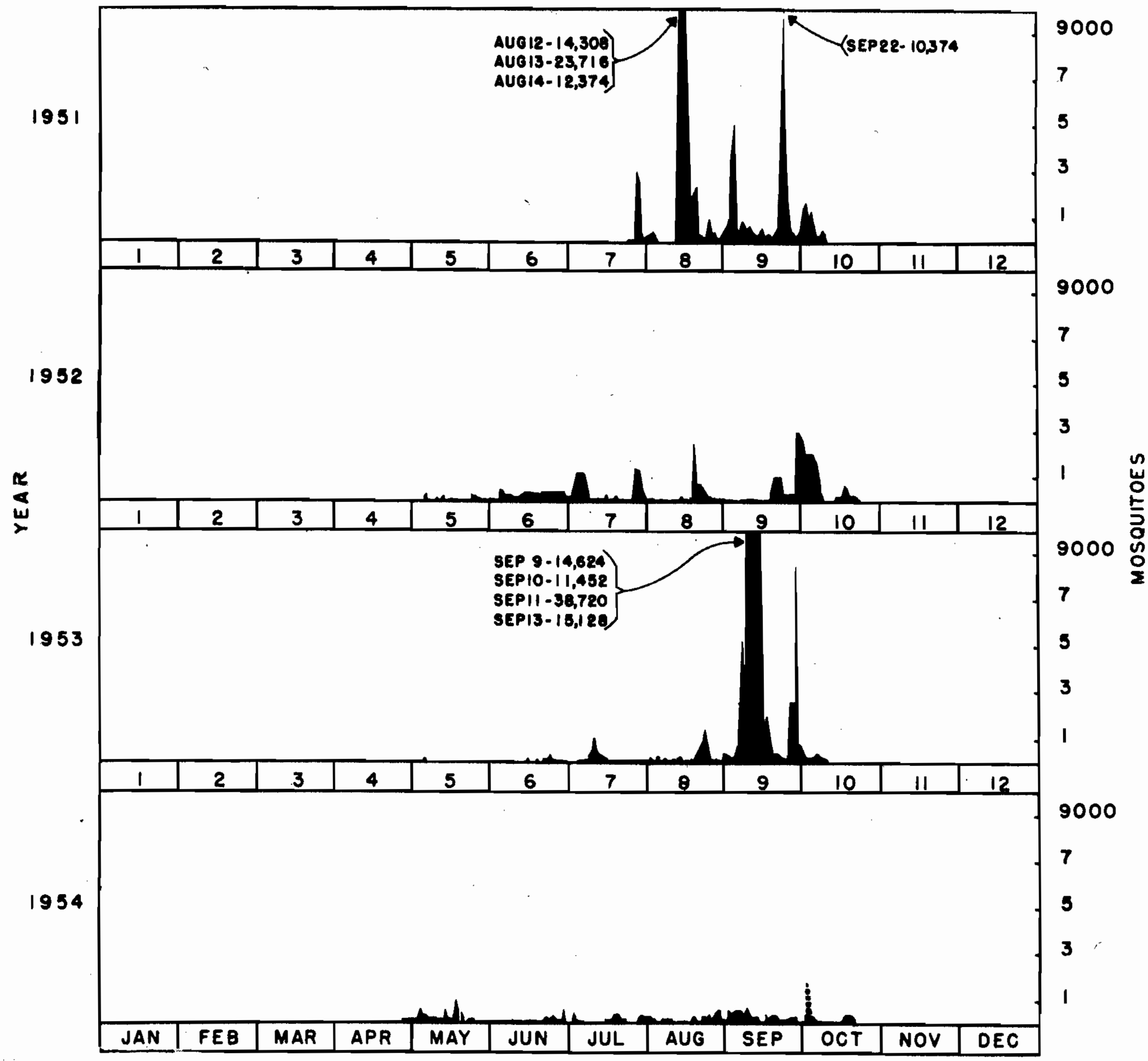
Degrees F.

Larval growth rates are influenced greatly by temperature. Thurman, et al. (1951), Husbands and Rosay (1952), and Keener and Edmunds (1954), describe this influence in some detail. This information is basic to the prevention and control of irrigated pasture mosquitoes. Prevention is based upon the removal of all water from fields 4 days after application. Control is based upon (1) initiating spring and early summer insecticide application to fields, (2) synchronizing larviciding with the most susceptible instars and, if possible, the smallest water area needing treatment.

Initiating spring and early summer treatment in irrigated pasture cannot be determined by seasonal temperatures alone. Nor can this factor be applied safely to an entire abatement area. The theoretical application must include the knowledge of the time that water remains on individual fields following irrigation. Previous experience shows that water can be measured during a single irrigation in major ponding areas of fields, and from this the maximal duration of standing water can be computed safely for each field by taking field topography into consideration. Using the maximum duration of standing water per field as a factor, fields can be classified and placed into several categories, each to receive treatment when temperatures indicate that successful emergence under the most extreme conditions of irrigation is potentially possible. Maps of field by categories could be used to initiate operators into new areas, to schedule operations, or to determine the number of abatement operators needed as the season progressed. Until this method is used, temperature-growth relationships of mosquitoes cannot be safely applied to the initiation of area-wide control of *Aedes* species.

Species composition is related to temperature in irrigated pastures. Records show that the immature stages of *A. nigromaculis* and *A. dorsalis* are greatly reduced when

Figure 1. Adult mosquito collections taken in an isolated study pasture, Madera County, during 1951, 1952, 1953, and 1954, showing the distribution and abundance of all species of mosquitoes as measured by a New Jersey type light trap located in the immediate vicinity of the field.



maximum temperatures fall below 70° F. This is attributed to the failure of most *Aedes* eggs to hatch in the field when irrigation water is below 70° F. *Aedes* species are replaced by *Culiseta* species in the fall and winter in water remaining after rainfall. Overwintering *Aedes* eggs are conditioned to remain quiescent or dormant until spring temperatures go above a specific level or possibly until repeated drying and wetting, plus increased temperature, conditions a portion of the eggs to hatch during rain or irrigation periods. Records in the Madera County Study Pasture show that *Aedes* larvae are ordinarily first recorded in small numbers during March when average temperatures are 50° F. or above. The first major increase in *Aedes* occur in April, which also is related to the beginning of the irrigation season in some areas. Many of the early season hatches fail to survive the extended growth periods produced by cool weather. Therefore, re-seeding of the field with eggs does not occur. Repeated floodings and hatching without re-seeding of the field reduces the number of overwinter eggs. However, great numbers of eggs are apparently conditioned to remain quiescent until later warm periods when adults can successfully emerge.

Meteorological studies and the distribution and abundance of mosquito populations is recognized to be of primary importance. Analysis depends upon future developments in studies of mosquito behavior and environment.

PONDING AND IRRIGATION

Ponding results from several conditions. Improper leveling, poor cattle management before or after crops are established, improper irrigation, pasture deterioration, high water table and poor drainage (or soil conditions) are some of the major factors responsible for this problem. Ponds in pastures have not been classified according to mosquito productivity. However, variations in productivity have been recorded for comparative ponds in the same pasture. Species composition by ponds has been recorded, Table 3, but no environmental relationships have been determined to date to completely explain the differences noted. Over-irrigation generally provides sufficient standing water in ponds to increase *Culex* species. During 1954, in the Madera County Study Pasture, prolonged irrigation periods in which water seeped upon the field for several days during each irrigation developed new problems in mosquito analysis. Records show that *Aedes* larval production declined after June with an equally great reduction in adult production. The fact that much of the productive surface of the pasture was wet for several days following emergence of *Aedes* adults may have contributed to this reduction. Gravid females in laboratory tests seldom select extremely wet areas for oviposition unless forced to do so. It also has been noted that during a period when water covers the field surface, female mosquitoes will move off the field and into surrounding areas and return gradually as the field surface reaches a condition comparable to a soil at or below field capacity. Failure to reseed the field with eggs because it was not attractive to gravid females may have contributed to the reduced *Aedes* population.

Ponding influences the distribution, abundance, and kinds of plants associated with pastures. Few pasture plants will survive prolonged submergence of the root system. Eventually, most types will be replaced by Dallisgrass or similar water-loving types. In some cases replacement does not occur, and this results in areas without vegetation. This change in cover influences species composition.

Frequency of irrigation has been related to larval densities and resulting adult populations (Husbands, Rosay, 1952). Adjusting irrigation cycles and/or the amount of water delivered to a field per irrigation will help to decrease control problems. However, certain other problems must be taken into consideration when improving irrigation efficiencies to decrease mosquito densities. In some cases it theoretically can increase mosquito production. Shallow irrigations, when alternated with heavier irrigations, have been shown to increase mosquito problems. A sudden increase in the depth of water flowing between border ridges may flood *Aedes* eggs that have accumulated from several broods of emerging adults. Major outbreaks may occur under these conditions. However, this same factor can be used to reduce potential problems if done under entomological supervision with the intention of gaining complete chemical control of resulting larvae and remove this hazard from specific fields near heavily (human) populated areas.

Ingenuity in the application of the methods suggested depends upon need. Some of the proposed or suggested applications would not be considered practical except under emergency conditions.

SOIL MOISTURE

Soil moisture reflects many important aspects of complex ecological problems associated with mosquito production. Only a few of these problems have been examined. Soil moisture is directly related to irrigation efficiency which in turn is related to mosquito production. Soil surface moisture is related to *Aedes* species mosquitoes oviposition habits, to viability or ability of *Aedes* eggs to survive, to hatching (conditioning factors), and to the survival of late fourth instar larvae and pupae in the absence of surface water so that these stages will eventually produce adult mosquitoes. Several of these factors have been mentioned in more detail in previous papers (Husbands, Rosay, 1952, 1953, and Husbands, 1953).

Some special aspects of this problem not previously reported were examined by means of a special study initiated in 1953. Employing a Bouyoucos (1948) soil moisture meter and nylon electrical resistance units, soil moisture was measured at depths of six and twelve inches near the top, center, and end of selected borders (checks) in th Madera County Study Pasture.

A comparison of seasonal measurements in two selected stations shows several interesting relationships. As an example, Bouyoucos station number 4 and 5 located respectively 123 feet and 381 feet below the main irrigation lateral can be examined critically, Figure 2.

These records show that below 12 inches soil moisture during a rainfall period does not increase greatly. In addition, station 4, which generally receives and retains water on the surface only during the flow of irrigation, shows no great increase in soil moisture below 12 inches during the entire irrigation period of 1954. However, the top six inches shows an increase in soil moisture from May through August. From September to the end of the irrigation season, although water remained on the surface for longer periods of time, there was a gradual loss of moisture at both the six and twelve inch depths until the last irrigation replaced this to some extent. This process was repeated in other measurement stations located at the top of borders. However, measurements taken in several ponding areas or stations located at the bottoms of borders

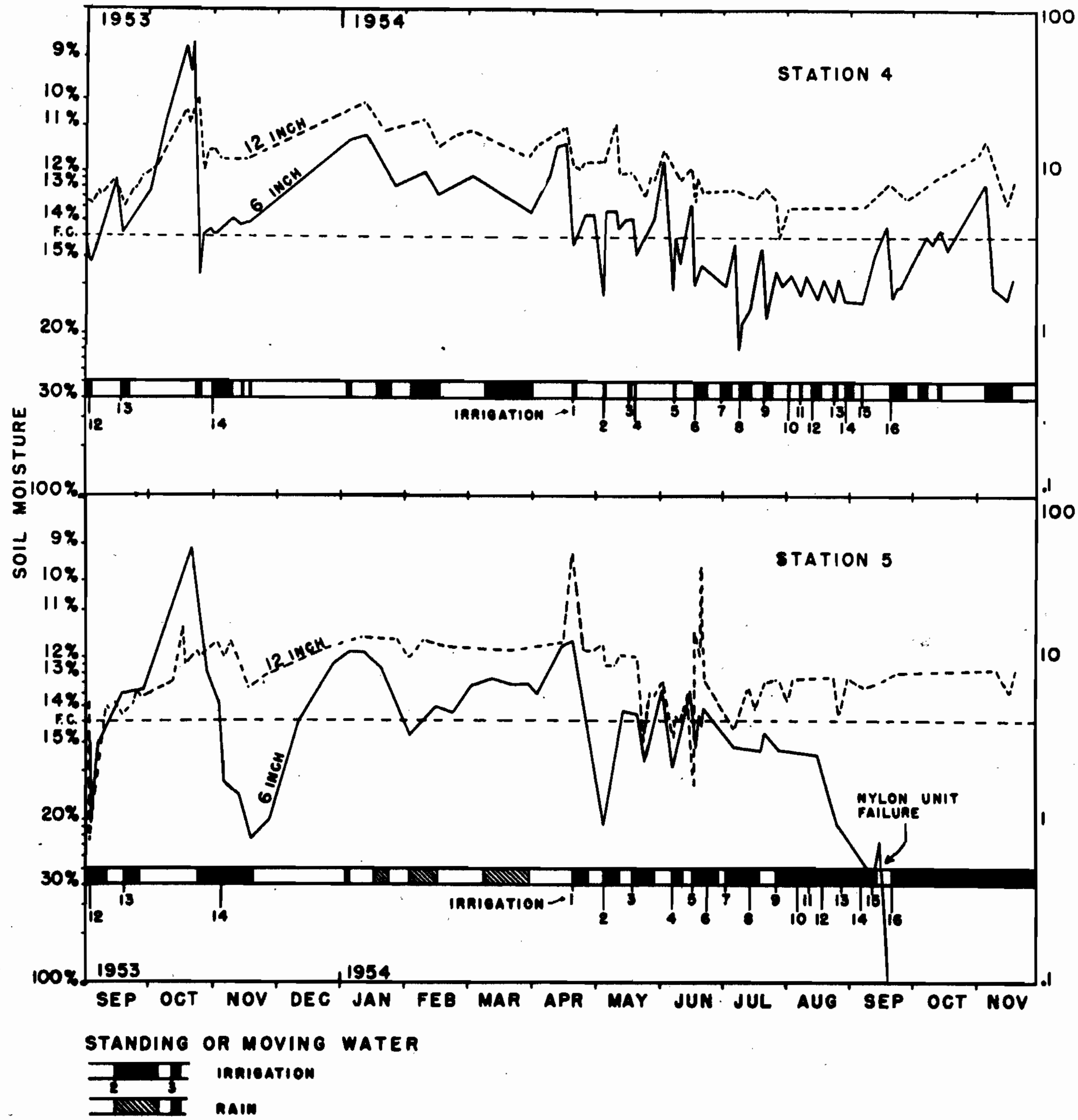
TABLE 3.

Comparison of Aquatic Stage Collections Taken at Selected Stations Madera County Study Pasture — June 25, November 9, 1951, 1952, 1953, 1954 — Showing some of the variations in species composition occurring in two ponds located in different parts of the study pasture.

	Percent Station 1				*Percent Station 5*			
All Species	1951	1952	1953	1954	1951	1952	1953	1954
Aedes dorsalis	4.60	1.80	4.98	2.86	2.56	3.67	0.80	0.16
A. nigromaculis	54.60	15.99	29.71	15.80	48.04	45.85	49.73	3.87
Culex tarsalis	6.80	32.19	18.27	29.55	17.02	19.50	11.45	48.14
All Others[1]	33.97	49.95	46.98	51.76	32.36	30.94	37.98	47.81
Dominant Species								
Aedes dorsalis	7.16	3.61	9.40	5.94	3.79	5.32	1.30	0.31
A. nigromaculis	82.57	31.98	56.09	32.75	71.03	66.41	80.21	7.42
C. tarsalis	10.27	64.39	34.50	61.28	25.17	28.25	18.47	92.25

[1]All other species plus early instar *Aedes* and *Culex*, with *Aedes* species in the majority.

Figure 2. Soil moisture measurements taken by nylon resistance units located at 6 and 12 inches depth in an irrigated pasture, Madera County, showing seasonal variations in soil moisture in two stations, No. 4 located near the top of a strip check and No. 5 located at the bottom (ponding area) of the same strip check.



shows that standing water failed to penetrate below 12 inches in amounts sufficient to bring the soil moisture above field capacity. Soil samples taken with a soil tube confirmed the reduced moisture content in the soil below 12 inches in ponding areas. At the 6 inch zone in Bouyoucos station 5, moisture exceeded field capacity continuously after June, 1954, which eventually led to the deterioration of the nylon unit and its failure. The comparison of soil moisture immediately following each irrigation period with soil moisture content at the beginning of each period shows that most irrigations were not adjusted to the requirements of plants in the pasture. For this reason and others, irrigation efficiency was very low.

It also can be seen that water was generally applied so frequently and over such long periods that the soil surface was generally wet (in the areas not ponded) from one irrigation to another. As mentioned before, mosquito production can be related to this condition. The reduced infiltration rates increase the problem of ponding and the excess soil moisture contributes to soil deterioration and the growth of pond areas. This increases the opportunity for the survival of mosquitoes, especially the *Culex* species. However, it is interesting to note that *Aedes* species populations were reduced during this same period. Several seasons of comparison will be required before this phenomenon can be evaluated correctly.

SUMMARY

Weather, ponding and irrigation, and soil moisture in respect to mosquito production are reviewed briefly on the basis of observations in selected study pastures. Relationships are presented to show the complexity of the problems involved, to suggest some methods of using this information to assist present mosquito control operations, and to point up potential sources of material upon which to develop biological or source reduction control.

ACKNOWLEDGEMENTS

It is impossible to acknowledge the great assistance rendered to this investigation unit by the many persons involved in the preparation and development of the material mentioned in this review which covers work from 1950.

Special mention should be made of the pioneering and continuing efforts of the Bureau of Vector Control, California State Department of Public Health, Richard F. Peters, Chief; the administrative and technical assistance of Dr. Basil G. Markos, In Charge, Vector Investigations Unit, Bureau of Vector Control; and the development of the program by the Operational Investigations Committee, California Mosquito Control Association, Theodore G. Raley, Chairman.

The very capable assistance of Miss Bettina Rosay, CMCA, provided excellent entomological identifications and summaries of data. Malcolm S. White, B.V.C., assisted in the preparation of charts and Daniel S. Stephanian, B.V.C., assisted in field measurements.

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Mr. Davis: This paper also will be jointly presented as it was jointly prepared. I have been very much interested in this conference. I'm very happy of having the opportunity of attending. It's an interesting thing to me to attend irrigation conferences all the time; then come to a conference such as this, and find that we are thinking along the same lines. The same things that will help the people in irrigation will help those in mosquito control.

AN INDICATION OF THE RELATIONSHIP BETWEEN IRRIGATION PRACTICES AND MOSQUITO PRODUCTION[1]

STERLIG DAVIS[2] AND RICHARD C. HUSBANDS[3]

A joint Irrigation-Mosquito Study was initiated by the Agricultural Research Service, U. S. Department of Agriculture and the Bureau of Vector Control, California State Health Department, during the summer of 1954, in the Central Valley of California. Research has shown that a large proportion of the mosquitoes produced originate in irrigated pastures in this area. The purpose of this study was to evaluate present irrigation practices in an attempt to establish the relationship between irrigation efficiency and mosquito production.

METHODS AND PROCEDURES

Irrigation efficiencies were determined at three sites located near Merced, California, within the Merced County Mosquito Abatement District. Fields were selected to represent general water management practices followed by farmers on the predominant soil types of the area including Landlow and Lewis clay, Wyman and Yokohl clay loam, and Landlow and Lewis silty clay loam. In general, these soils have a hardpan which occurs at variable depths between 18 inches and 54 inches below the surface. The relatively low intake rates, in addition to inadequate land levelling for irrigation, cause varying degrees of surface ponding of water following irrigation. In most instances, the land has a slope of about 0.2 per cent, or less. Both contour (Field No. 1) and parallel border (Fields 2 and 3) methods of irrigation were evaluated. All fields had been utilized as irrigated pastures several years prior to initiation of this study. Ponding areas contained water grass, were barren, or covered with the debris of dead grasses. The length of time water was applied to the field determined the success or failure of these small ponds as a source of adult mosquitoes.

The method used for evaluation of border irrigation is described by Criddle and Davis (1951). Measurements include soil moisture determinations taken before and after irrigation, the amount of water applied and runoff from each field, rate of advance and recession of water applied, and intake rates. Irrigation efficiency is expressed as a percentage of the amount of water retained in the soil, plus that used by the crop during irrigation, to the total amount applied at each irrigation.

Mosquitoes were sampled in the aquatic stages by the standard dipper method. Daily samples were taken following irrigation, or until larvae reached the fourth instar, at which time insecticidal control was applied.[4] Samples were examined for rate of development and species composition. Sampling was conducted at selected stations where standing water and ponding areas occurred. Standing water areas corresponded, roughly, with areas determined by the recession rate, and ponding areas represented those not drained by normal surface drainage. Adult production was determined by larval growth rate and temperature relationships to compute a theoretical adult mosquito emergence period. Mosquito "produc-

[1]For presentation at Joint Session of American Mosquito Control Association and California Mosquito Control Association Conference, January 24, 1955, Los Angeles, California.

[2]Project Leader, Irrigation, Western Soil and Water Management Section, SWC, ARS, USDA.

[3]Project Leader, Mosquito, Bureau of Vector Control and C.M.C.A.

[4]Field No. 1 received DDT 2½% emulsion applied by jeep. Field No. 2 was treated with Parathion applied by airplane.

tivity" also was computed on the basis of larval instar ratios.

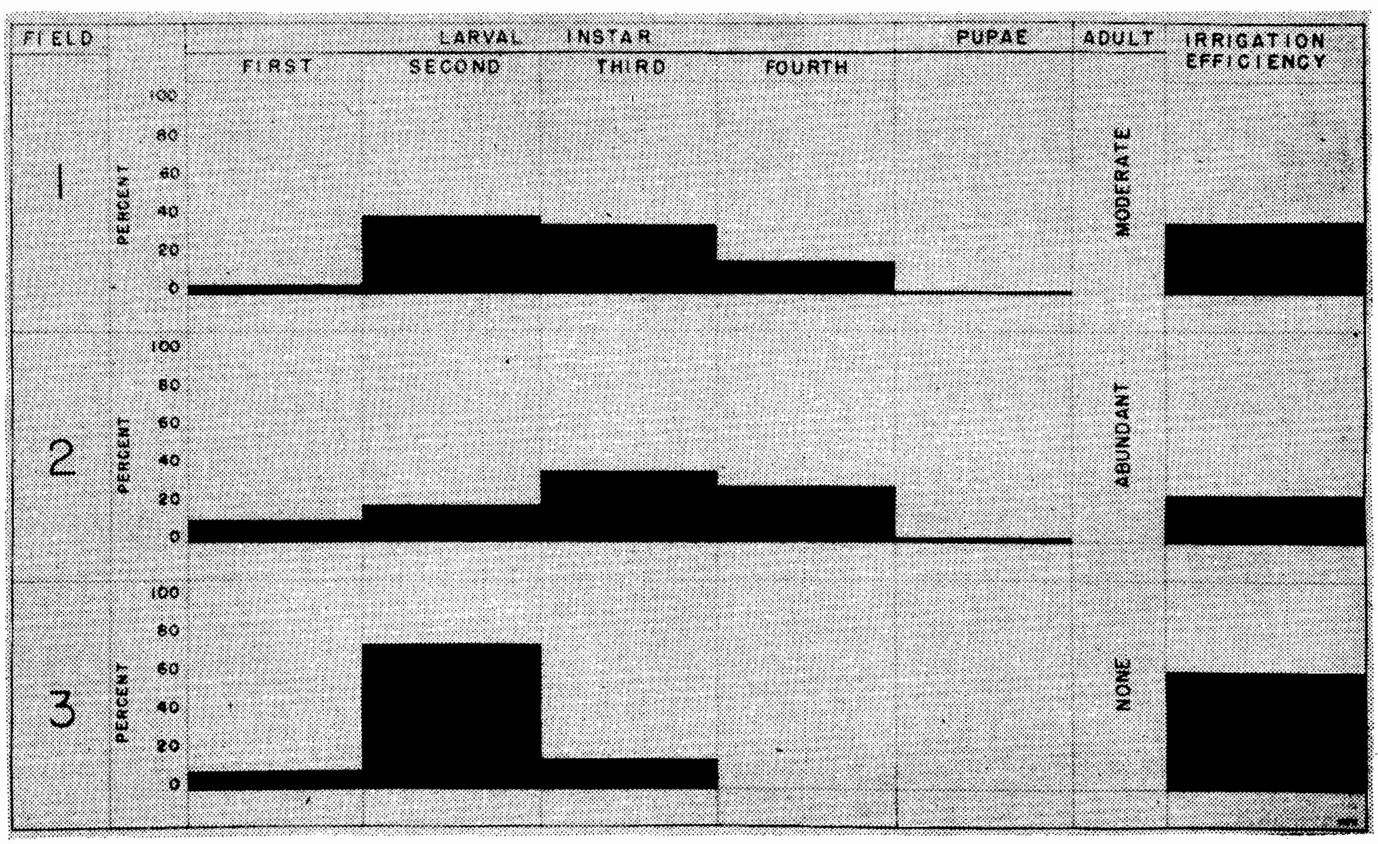
A method of mosquito analysis tentatively called "Sample Opportunity Index" was used to evaluate field productivity. Sampling stations reflect the changing relationship between water surface areas and the growth of *Aedes* species mosquitoes. Increasing productivity per field is indicated by an abundance of late instars in samples and decreasing productivity is shown by an increasing ratio of early instars in samples. The significance of these larval indices to adult mosquito production has not been shown beyond the comparative description for these three fields given in the terms "abundant," "moderate," or "none." Actual adult production could not be measured since these three fields were under chemical control. Based upon previous studies, with certain reservations, the greater the area of water available for larval development, pupation, and adult emergence, the greater the resultant mosquito population (Husbands and Rosay, 1952, 1953, and Husbands, 1953). Measurements were made of larval densities and standing water areas to determine a production index. However, under certain conditions, the stranding of pupae on damp soil with resultant successful adult emergence, complicated this method of measurement. Adult emergence, when effected and due to control failure, provided additional knowledge.

RESULTS

Figure 1 graphically summarizes the relationship between irrigation efficiency, sampling opportunity, and mosquito production for the three fields studied. It will be noted that with an irrigation efficiency of 35 per cent, mosquito production on Field No. 1 was described as "moderate" per unit area. Large ponds at the top of the field, as well as small scattered ponds within the field, were low in density, averaging about 3 larvae per dip. Some larvae were lost to the drainage system by runoff. Fourth instar *Aedes* species larvae constituted approximately 17.5 per cent of instars taken at all stations. Second and third instars were recovered most frequently and constituted 40.5 and 36.0 per cent, respectively, of the samples taken during the period of study. The decrease in the ratio of fourth instar larvae to all other instars, in comparison to the other fields studied, reflects the decreasing opportunity for successful adult emergence. Species of mosquitoes taken were almost entirely *Aedes nigromaculis* and *Aedes dorsalis*. Very few *Culex* species were found.

An average irrigation efficiency of 25 per cent on Field No. 2 was the lowest observed, even though it was recently releveled. One factor which contributed to the extremely poor efficiency of this field was the shallow root zone (less than one foot) due to presence of a high water table, in addition to poor management and operation of the irrigation system. Irrigation water collected in large shallow ponds in the upper two-thirds of the field. These ponds gradually were reduced in size and eventually formed small ponds that lasted two to five days after the water was shut off. Since water was applied continuously for two or more days, these small ponds persisted for seven or more days from the day that water was first applied. However, the major source of adults occurred in ponded

Figure 1.—Variation in larval percentage with sampling opportunity as related to mosquito production and irrigation efficiency at three representative sites near Merced, Calif. — 1954.



areas located at the foot of each check, forming one continuous body of water along the bottom of the field, and generally lasted from one irrigation to the next. Following irrigation, water receded into this area causing submergence of approximately the lower one-fifth of the border checks. This condition could have been improved with adequate drainage to allow removal of surface runoff, and to permit extension of root systems to greater depths within the soil profile. Under such conditions, fewer irrigations would be required because of greater water storage in the root zone. Efficiency of irrigation could also be improved on this field by utilizing a larger head of water for a shorter period of time.

Mosquito production was high, or "abundant," and aquatic samples showed that fourth instar *Aedes* species larvae constituted 29.4 per cent of all instars taken. Second and third instar larvae constituted 19.8 and 36.9 per cent, respectively. The increase in the ratio of fourth instar larvae indicates that a greater opportunity was present in this field for pupation and adult emergence. Species of mosquitoes taken in samples were: 92.4 percent *Aedes* species, and 7.6 percent *Culex* species. *Aedes* species were primarily *Aedes nigromaculis* and *Aedes dorsalis*. *Culex* species were primarily *Culex tarsalis*. Larval densities averaged 14 larvae per dip. This field was the most abundant producer of mosquitoes of the three studied.

Good management of water by the irrigator on Field No. 3 resulted in an irrigation efficiency of 66 per cent, even though some spots needed to be releveled. During one irrigation cycle, a few adult mosquitoes were produced when back flow of water upon the lower portion of the field occurred due to failure to close a drain valve following irrigation. Aquatic samples, except for the occasion mentioned, did not contain fourth instar larvae and a high percentage, or 75.4 per cent of the larvae recovered by dipping, was second instar. Only *Aedes* species mosquitoes were taken from the field, and these were primarily *Aedes nigromaculis* and *Aedes dorsalis*. The absence of mosquito production in this field reduced larval densities. Mosquito production has been low or absent on this field for many years, as recorded by the Merced County Mosquito Abatement District. However, surrounding areas were sometimes responsible for mosquitoes which reseeded the field with *Aedes* eggs and produced the larvae measured at each irrigation.

Evaluation of existing water management practices on three typical fields in the Merced County Mosquito Abatement District indicates that ponded water in pastures is one source of mosquito production. Furthermore, the longer sampling opportunity that was possible on fields with low irrigation efficiencies indicates the need for better water control and management to minimize surface ponding. The extremely low irrigation efficiencies obtained is not only a wasteful use of our water resources, but appears to be definitely correlated with the problem of mosquito production. Further studies are being made in this area to support the preliminary results presented.

ACKNOWLEDGEMENTS

Many persons were associated with the development of this program. Special mention should be made of Lloyd E. Myers, Jr., Engineer, A.R.S., U.S.D.A., who was instrumental in bringing together the various elements concerned in this program. Excellent cooperation was obtained from the Merced County Mosquito Abatement District, John O. Stivers, Manager. The Operational Investigations Committee, California Mosquito Control Association, Inc., and members of the Vector Investigations Unit, Bureau of Vector Control, provided valuable administrative and technical assistance. Mosquito identifications were made by Bettina Rosay, Entomologist, C.M.C.A.

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SOME OBSERVATIONS ON *AEDES NIGROMACULIS* EGGS

BETTINA ROSAY[1]

A study of *Aedes nigromaculis* eggs has been undertaken with the ultimate aim to control mosquitoes through field treatment of eggs, either (1) by inhibiting hatching through interference with the chemical action of growth substances in the eggs, or (2) by stimulating natural or unnatural hatching with chemical, physical, or mechanical means to decrease egg densities in fields and thereby decreasing problems of control.

The preliminary steps of the investigation included obtaining eggs that would act in a consistent manner under test conditions. The procedure has been to control the temperature and humidity ambient to the eggs during the period of embryonic development, which is the 3 to 5 days following oviposition. Constant relative humidities were maintained in tightly-closed jars in which there were super-saturated solutions of selected salts; constant temperatures were maintained in incubators.

After specified lengths of time subsequent to flooding, all unhatched eggs were examined to find reasons for not hatching. Throughout the work considerable variation in egg actions was noted, and efforts were made to find out why the variations occurred.

Eggs could be divided into two groups, according to their action: those that hatched when flooded, and those that did not hatch when flooded. Both could occur within a single egg batch.

Incubation at 85° F. and 95-100 percent R.H. has consistently produced at least 80 percent hatching of egg batches within 24 hours after flooding.

There were three types of eggs that did not hatch due to a retarding of growth before, during, and after embryonic development.

I. Delayed embryonation. There was no embryonic growth under certain conditions within the usual time allowed for the process; embryonation proceeded later under favorable conditions.

II. Immature embryos. Growth was halted at a point short of maturity: segmentation incomplete, yolk sac still present. A few immature eggs appeared in nearly every

[1]Entomologist, California Mosquito Control Association and Bureau of Vector Control, California State Department of Public Health.

egg batch. These eggs matured and hatched after gradual drying and reflooding.

III. Quiescent eggs. The shells contained fully developed, live embryos that did not hatch when flooded. If quiescent eggs were mechanically broken open to release the embryos, the larvae exhibited only feeble muscle movements and did not develop beyond the embryonic state. They lived from a few minutes to five days. This implies that the act of hatching involves more than the mere opening of the egg shell.

The hatchability of an egg seems to be influenced by the egg shell which is composed of three units. The outermost covering is sculptured and is easily peeled away.

The middle layer, or dark chorion, can be dissolved by sodium hypochlorite. It apparently controls water loss in protecting the embryo from excessive drying. When the chorion is in place, eggs can be dessicated to the point of near-complete collapsing, the embryo dehydrated, and the eggs stored. When such eggs are replaced in a moist or wet environment, the embryo will hydrate; the shell will regain its normal shape, and the live larva emerges. However, if the chorion is removed before drying, the action is irreversible, i.e., the embryo is killed by water loss.

The inner membrane, the transparent embryonic envelope, is highly resistant to such media as mineral oil, xylol, sodium hypochlorite, and alcohol in which dechorionated eggs have been immersed. Dechorionated quiescent eggs have been allowed to remain in the media for extended lengths of time without injury to the embryo. When dechorionated collapsed eggs were placed in water-soluble dyes, water but not the dye was observed to pass through the membrane.

The information presented is based on laboratory data, and the findings should not be interpreted as happening in the field until further observations are available.

FURTHER STUDIES DURING 1954 ON BLUE-GREEN ALGAE — A POSSIBLE ANTI-MOSQUITO MEASURE FOR RICE FIELDS

RICHARD W. GERHARDT, *Entomologist*
Cooperative California Mosquito Control Association
Bureau of Vector Control Rice Field Ecology Study

During 1953 preliminary studies were completed which demonstrated the deterrent effect of certain species of blue-green algae on mosquito larvae in rice fields. In addition, it was demonstrated that it is possible to transplant blue-green algae from rice fields where such algae occur naturally as dominant organisms to other rice fields where they were found to be absent or to occur only in minute quantities. This transplant method used rice stubble, cut and raked, along with debris from a rice field known to support an abundant growth of *Anabaena* (Gerhardt, 1953), in the belief that this material would serve as a carrier of algal spores. The practicality of this method seemed in need of substantiation, and was undertaken during 1954.

Demonstration of the mode of action of these algae as they affect mosquito larvae, has been undertaken by the Department of Plant Nutrition, University of California. Some work already has been completed and additional studies are planned.

Experimental work to gain additional information concerning the problems of transplanting blue-green algae into rice fields was completed during 1954. The information gained sheds light on the biology of blue-green algae in rice field habitats and indicates problems for future study as related to mosquito control work.

Methods and Procedure

During the winter months of 1953-1954, rice stubble was cut and gathered from the Smith rice field near Nelson, California. This field is located in Butte County, Township 20N, Range 1E, Section 31. The field has been under study for two years previous to harvesting the stubble, and is known to support a dominant growth of *Anabaena unispora* Gardn. Gerhardt, 1953).

The stubble was transported to the Rice Field Mosquito Ecology Project Center near Lincoln, California, with authorization from the Agricultural Commissioners of Butte and Placer Counties. All subsequent transplants were made with permission of the Agricultural Commissioners of the respective counties into which this material was introduced.

The stubble was stored on an elevated slat platform, which allowed air to circulate beneath the straw, and was covered with tarpaulins.

During March the stubble was transported to a nearby ranch where it was fed through a chopping machine of the type ordinarily used to chop forage crops. The processed stubble then was sacked in common cloth "feed" sacks and stored in a dry barn.

After processing, the stubble was in the form of chaff, the largest straw fragments not exceeding 2 inches in length.

Five rice fields were chosen as experimental plots. These were widely distributed in the rice growing areas of the State, as follows:

Butte County, T. 18N, R. 2E, S. 25.
Yuba County, T. 17N, R. 4E, S. 15.
Yolo County, T. 12N, R. 2E, S. 19.
San Joaquin County, T. 3N, R. 6E, S. 35.
Stanislaus County, T. 3S, R. 9E, S. 11.

Rice stubble was broadcast by hand into the experimental sections of these fields. The stubble was placed on the completely cultivated soil before flooding in all except the Stanislaus County field plot where the stubble was broadcast on the surface of the water shortly after the field was flooded.

The experimental plots were located in the last few checks of the fields (down stream in respect to water currents), except in the case of San Joaquin County, which was a small isolated field of only one check which had no outlet.

Control (untreated) plots were established at the upper ends of the fields, except in the case of the San Joaquin County field where a similar, neighboring field was used as a "control."

Since it is known that blue-green algal species of the genus *Anabaena* generally require a trace of molybdenum for growth, about 8 oz. of ammonium molybdate was applied to each study plot.

The rates of application of the rice stubble and of the ammonium molybdate varied in each field. Eight sacks of chopped stubble were applied to each experimental plot. Each of these sacks contained about 10 lbs. of dry stubble.

[1]The Author wishes to acknowledge, with thanks, the aid given by Mr. Leon Hall and the managers of the Butte County, Sacramento-Yolo County, San Joaquin County, Stanislaus County, and Sutter-Yuba County Mosquito Abatement Districts.

Applications were as follows:

Butte Co.	6 acres	8 sacks	1.3 sacks per acre
Yuba Co.	2 acres	8 sacks	4.0 sacks per acre
Yolo Co.	13 acres	8 sacks	6.0 sacks per acre
San Joaquin Co.	½ acre	8 sacks	16.0 sacks per acre
Stanislaus Co.	1 acre	8 sacks	8.0 sacks per acre

The success of the inoculation in each experimental plot was judged as follows:

1) The presence of blue-green algae in the study plots was determined by field observation and microscopic examination of collections of algal mats and plankton samples. Plankton collections were made with a Sedgewick-Rafter funnel. Water was collected from the discharge weirs of the respective fields. An exception to this method was the San Joaquin County field which had no outlet. In this case, water samples were taken from midfield.
2) The transplants were tested as to possible toxic effects on mosquito larval populations. Population samples for mosquito larvae were obtained by the conventional dipper method and records were kept for each of the experimental and control plots, except in the case of the Stanislaus County field, where distances prevented regular visits to the field.

Results

Blue-green algae of the genus *Anabaena* were found in abundance in all but one (Yuba County) of the rice field experimental plots. Each of the fields, except the Yuba County field, showed heavy spring blooms of blue-green algae. The blooms were first evident in the experimental plots. In one field (Butte County) the bloom extended into the remainder of the field. The bloom in the upper portion of the field died out by mid-July but the algae persisted in the experimental plot.

After the original bloom had run its course, the algae declined in abundance and in one field (Yuba County) virtually disappeared.

The relative abundance of the genus *Anabaena* in the test and control plots is expressed as a percent of the total algal flora present. The findings are summarized in the tables below:

Early June

	Experimental Plots	*Control Plots*
Butte	80% *Anabaena*	10% *Anabaena*
Yolo	40% "	trace
Yuba	10% "	10% "
San Joaquin	80% "	trace
Stanislaus	40% "	10% "

Mid-July

	Experimental Plots	*Control Plots*
Butte	50% *Anabaena*	20% *Anabaena*
Yolo	10% "	trace
Yuba	trace	20% "
San Joaquin	50% "	trace
Stanislaus	25% "	10% "

Mid-August

	Experimental Plots	*Control Plots*
Butte	50% *Anabaena*	trace
Yolo	10% "	trace
Yuba	trace	80% *Anabaena*
San Joaquin	50% "	10% "
Stanislaus	20% "	10% "

Findings during the remainder of the season (mid-August to late September) were essentially as those shown for mid-August.

A summary of the larval collections for the season is given in the graphs on Page 122.

Discussion

The data in the preceding tables show that all except one of the test plots (Yuba) displayed an abundance of *Anabaena* during the early part of the season. No scientific explanation can be given at present for the decline in abundance of the blue-greens following the early bloom. However, it may be that insufficient amounts of molybdenum were supplied so that this element was eventually depleted. This assumption is further strengthened by the fact that the transplants were near the end of each field so that the water in these checks was continuously displaced throughout the season.

Another possible explanation may be that the emergent rice plants shaded the water sufficiently to interrupt photosynthesis by the algae.

It should be noted that the control plot in Yuba County became dominated by a naturally occurring growth of *Anabaena* spp. in late July. This is not an unusual occurrence. The writer has observed mid-season blooms of blue-green algae in rice fields in previous years.

During the 1954 season observations in the study plots and other rice field areas revealed that larval infestations occurred in markedly insignificant numbers, as compared with previous seasons. In view of the small numbers of larvae found in the study plots, it was difficult to establish a marked or significant difference. Nevertheless, generalized observations on the absence of mosquito larvae in the presence of dominant blue-green algal growth was upheld; this was not as spectacular as it might have been if larval populations had been high. Of particular interest is the coincident decline of mosquito larval populations in all fields dominated by blue-green algae. This occurred in mid-July in all study areas.

Conclusions

During 1954 field studies revealed that it is possible to transplant blue-green algae from their natural rice field environments and encourage them to grow in a rice field where they would normally occur in only minute quantities.

Rice stubble cut from fields dominated by algal growths of the genus *Anabaena,* is a means of transplanting this alga. However, this method is inefficient in that large quantities of the stubble are necessary to achieve an abundance of the alga in the new environment. It is felt that greater success can be achieved when it becomes possible to utilize mass cultured algae as the source of inoculum. The feasibility of such transplants deserves study.

Generally, mosquito larvae were absent in test plots where there was an abundant growth of blue-green algae.

Summary

Blue-green algae of the genus *Anabaena* were transplanted from rice field areas in the vicinity of Nelson, California, to selected rice field study plots in Butte, Yuba, Yolo, San Joaquin, and Stanislaus Counties. An abundant growth of blue-green algae was observed in all but one of the test plots throughout the rice growing season of 1954. The plots exhibited early blooms followed by a gradual decline of the algae.

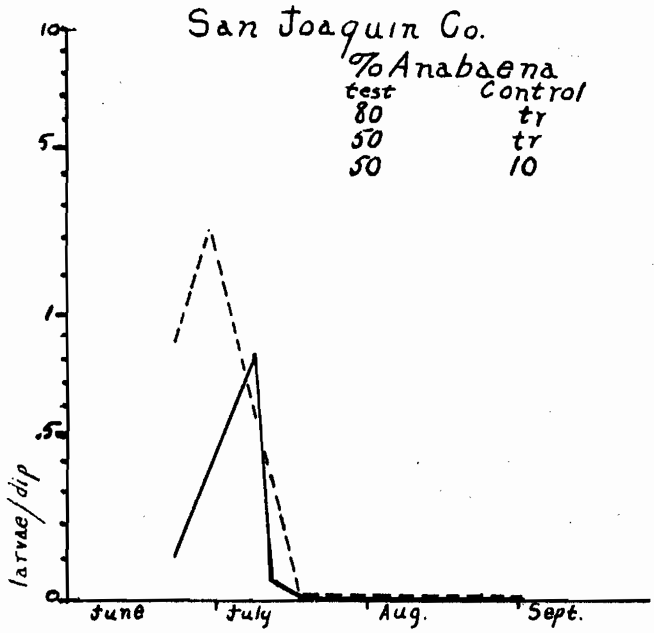
In general, mosquito larvae were absent from fields which supported an abundance of blue-green algal growth.

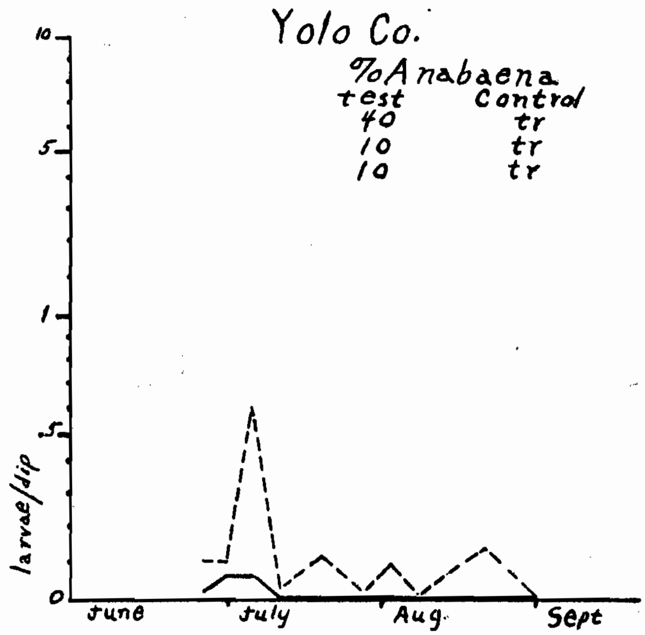
Further Studies on Blue-green Algae — A Possible Anti-Mosquito Measure for Rice Fields — R. W. Gerhardt

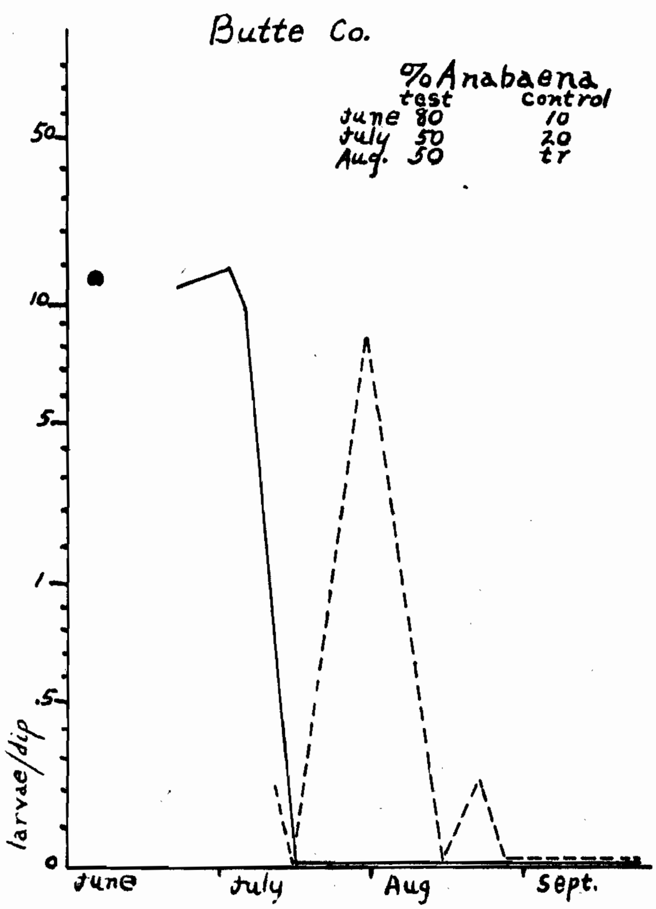
Larval Mosquito Populations
Algal Transplant Study Plots

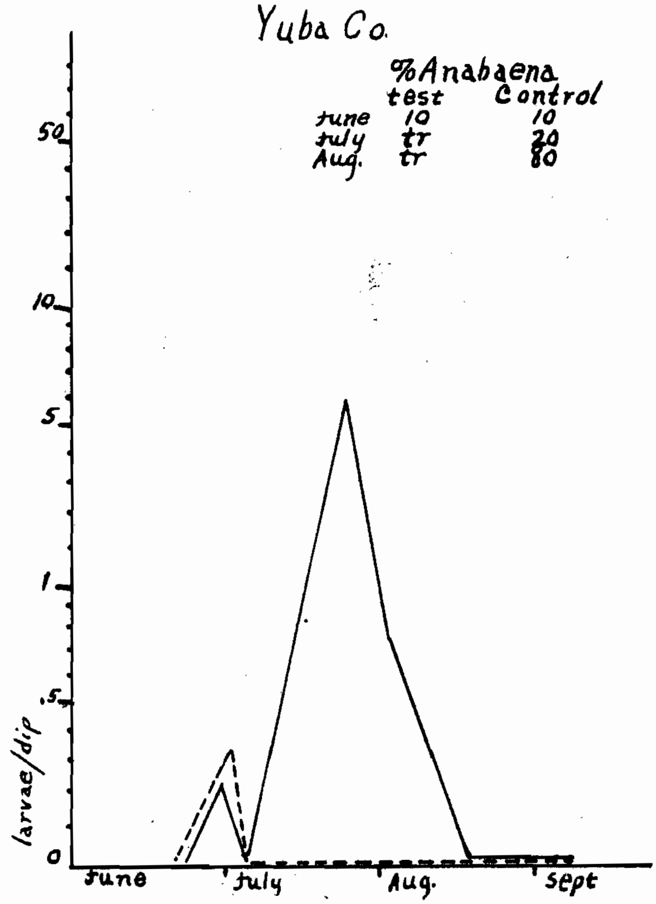
Semi-logrithmic Graphs

Study Plot ————
Control Plot - - - - -









The method of transplanting the algae by using rice stubble cut from fields supporting a dominant growth of *Anabaena* was found to be successful but not efficient as it should be for practical use. The possibility of achieving more successful transplants by using mass-cultured algae should be investigated.

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PROGRESS REPORT ON CULTURAL ASPECTS OF RICE FIELD MOSQUITO ECOLOGY

C. Luther Stone[1]

(Editor's Note: Prompted by the necessity for brevity, the following section on sub-projects has been extracted for printing from the more voluminous report originally submitted.)

Sub-Project No. 1 Rice Water Flow: Circulating vs. Non-Circulating.

The study area for this work was established over 8 plots which were 40 x 80 feet. In four plots water was circulated at a slow rate by the use of a 1½ inch re-circulating pump, while the other four plots were left at a constant water level to stagnate, with only enough water entering to maintain a constant level to compensate for loss by seepage, evaporation, and transpiration by the plants. All plots were planted to rice of the Colora Variety.

A minimum of 20 dips/plot were taken in each of the eight plots twice weekly to determine the mosquito larval counts. These counts were taken systematically from mid-June to mid-September, amounting to some 1040 dips per plot for the season.

Mosquito Production:	(A) Circulation	(B) Stagnation
Anopheline larvae:	21 = 0.025%	42 = 0.05%
Culicine larvae:	112 = 0.125%	713 = 0.80%
Totals	133 = 0.15%	755 = 0.85%

The above tabulation is encouraging toward slow circulation of rice water, which ultimately should prove a beneficial practice by growers if uniform circulation could be achieved throughout the rice fields. As experience shows, rice water tends to follow definite channels through the rice paddies and in remote corners little, if any, actual circulation is achieved. The installation of more irrigation boxes, with a more thorough spread of circulating water can be accomplished by engineering methods.

Sub-Project No. 2. Intermittent Submergence of Rice: Alternate Flooding and Drying.

This particular phase of the work was carried out over 12 rice nursery lots which were 20 x 100 feet each. These plots, during germination and early growth of rice from mid-June to mid-July, were flooded to a depth of 4 inches for 3 to 5 days; then water was drained off slowly and left to dry until the soil started to crust on the surface; then they were flooded again.

The results achieved by this work were essentially negative, except for one plot that showed an early invasion of culicines that was of short duration and of little significance. As an adjunct to this, mud samples were taken from these plots and placed in one quart enamel pans to see if eggs were present and, if so, whether they could be induced to hatch. The results here too, were disappointing and gave only negative responses to report.

Sub-Project No. 3. Check on Mosquito Production in Relation to Fertility Levels of Rice Soils Treated with Various Levels of Ammonia Sulphate (N) and Nugreen (Urea N) and Untreated Control Plots.

These plots, 18 in number, were checked twice weekly by standard methods and throughout the season did not yield any mosquito larvae. Even the control plots were negative. However, the experimental set-up on this project as designed by a University specialist was not suitable for a fair appraisal since the replicated treatments were laid out in large one-acre rectangular fields with no dividing contour levees between the respective plots. Hence, the rice irrigation water over these fertilizer treatments was subject to mixing from all the plots. Even chemical laboratory analysis of water samples failed to define any variance over the several treatment levels. However, it is thought significant that no mosquito production was obtained over soils that were treated with synthetic nitrogen fertilizers. In addition to this, the Llano Seco Rancho rice fields that were treated with 80 lbs. Nugreen, plus a heavy nitrogen green manure crops the previous winter, also resulted in no production of larvae. An attempt to locate a rice field that was not fertilized with nitrogen, either synthetically or naturally, to be a control also failed to materialize, since all rice is now fertilized in one way or another.

Sub-Project No. 4. Depth of Water in Pre-Warming Basins (Part of U. of C. Rice Cold Water Studies Conducted at Biggs Station and Bruce Wylie Station in Glenn County).

This project was set up as follows: (6" depth, open), (6" depth, weedy), (12" depth, open), (24" depth, open); these plots were replicated twice at Biggs and once at Bruce Wylie Station. Water circulation was relatively uniform and slow over all plots.

A minimum of 20 dips were taken in each of these 12 plots twice weekly to ascertain larval populations. These counts were taken systematically from mid-June to mid-September, amounting to some 1100 dips per plot for the season.

Total larval numbers dipped were as follows:

Biggs (A)	6"-Open	6"-Weedy	12"-Open	24"-Open
Anopheline	1	19	0	0
Culicine	325	91	1	0
Biggs (B)				
Anopheline	0	7	0	0
Culicine	6	6	0	0
Wylie (C)				
Anopheline	26	1	8	3
Culicine	20	0	15	5

The high count of culicines dipped in the 6-inch open warming basin was not an entirely ideal situation, inasmuch as the side of the basin where these larvae were taken was a shallow portion near the bank and in no way really representative of the conditions of the test. However, it does point out that if these warming basins are crudely constructed and create such congenial sites, they may lend themselves as a detriment. It appears that the 6-inch depth, open, basins will not be highly productive of mosquitoes if they are properly constructed and managed with a slow circulation of water. The larvae taken in the 12-inch and 24-inch basins were dipped adjacent

[1]Cooperative Operational Investigations, California Mosquito Control Association and the Bureau of Vector Control.

to the levee banks and under overlying watergrass. Interestingly enough, essentially all weeds were removed from the levee banks of the basins at Biggs, while watergrass was allowed to grow on the banks of the Wylie Station basins. The University, also, had its most significant results with the 6-inch depth, open, warming basins this year for warming the rice water. However, poor rice cropping of this past season, attributed to low summer temperatures, gave very poor yield records upon which to rest conclusions.

Sub-Project No. 5. Influence of Rice Weed Herbicides (Plant Hormones).

Several crude attempts were made during the season to make a cursory check on the possible influence of rice weed herbicides on mosquito production. The weed chemicals tested were 2-4D and M.C.P., the British slow acting hormone type weed killer now being used extensively in California rice fields for control of broad leaved weed pests.

These tests were carried out with use of distilled water, field water, and field water plus soil. The field water was rice irrigation water from which the larvae were dipped, and was filtered through a standard plankton net to remove the larger suspended organic materials. The concentrations of herbicide used ranged: 1/500, 1/1000, 1/2000, 1/3000, and 1/4000 parts by volume.

Culicine larvae of the second, third, and fourth instars were used in these tests since their abundance was much greater than first instar stages which were in short supply at times of the testing. Ten larvae of each stage were used in the treatments and a duplicate number were tested at the same time as controls.

The results showed that after six hours only six fourth instar larvae survived in the 1/4000 concentrate. After 48 hours only three fourth instars were alive. All the control series were alive after 48 hours. Air temperatures during the testing were 62° - 98° F., while the water temperatures ranged from 70° to 80° F. These tests were conducted under adverse conditions in an open end sheet metal warehouse free of direct sunlight. However, it was felt that these conditions, which were immediately adjacent to the rice-growing areas, may have simulated natural conditions to a close degree, except for the exclusion of direct sunlight.

In field practice rice is sprayed with these herbicides 50 to 60 days after planting. Field checks under actual conditions did not reveal positive results this season since no larvae were in the areas treated before or after spraying.

THE EFFECT OF AN INSECTICIDE TREATMENT ON SOME NATURAL INVERTEBRATE PREDATORS IN RICE FIELDS

Richard W. Gerhardt,[1] *Entomologist*
Cooperative California Mosquito Control Association—Bureau of Vector Control Rice Field Mosquito Ecology Project

Insecticides are only occasionally used to combat mosquitoes arising from rice fields in California. Since currently the only practical means of applying larvicides to rice fields is by aircraft, and since this rice field habitat is so extensive, such larviciding is too costly for widespread use.

[1]The author wishes to express thanks to Dr. L. M. Smith, Department of Entomology, U. of C. College of Agriculture, for advice concerning the preparation of this paper.

Some mosquito abatement districts in California undertake larviciding of rice fields by the following means. Frequently DDT wettable powder is applied with the seed rice at the time of sowing (Sperbeck, 1949; Portman, 1952). This method has been particularly successful in controlling early broods of *Aedes* mosquitoes. Some larviciding with liquid sprays or granular formulations is done near the close of the rice growing season in an effort to reduce the large, late brood of *Anopheles freeborni* Aitken which annually emerges from California rice fields. Most other larviciding is done in limited locations as an emergency measure for particular problem areas.

Since most larvicidal applications to rice fields are performed but once, without follow-up treatments, it was decided to observe the effect of such an application of insecticide on the rice field aquatic environment. Special attention was given to the effect of the treatment on naturally occurring invertebrate mosquito predators, since their depletion should be expected to result in a subsequently increased potential mosquito production in the treated area.

METHODS AND MATERIALS: A study plot was located in Yolo County, California, Township 9N., Range 2E, Section 31. The rice field at this location was newly checked and leveled for planting in the spring of 1954.

The last check of the field, covering 1214 sq. yards (approx. ¼ acre), was chosen as a study plot. Since the discharge weir for the field was located in this check, there was no danger of insecticides being carried into other parts of the field. The next to the last check (also approx. ¼ acre), immediately upstream in respect to water currents to the study plot and adjacent to it, was chosen as a control or untreated plot.

Determination of the mosquito larval populations of the two plots was made by the usual dipper method and the numbers were recorded. An effort was made to sample the population at random but still use a consistant technique.

Determination of the invertebrate predator population was made by using a large triangularly shaped aquatic dip net. Three under water sweeps, at arm's length, with this net covered approximately one square yard of surface area.

The predator population index was based on the numbers of three insects most commonly found and considered to be of importance as predators of mosquito larvae. These were: naiads of Odonata, all stages of Notonectidae, and adult Dytiscidae (Hinman, 1934). Other forms were collected but are not included in the data presented.

On September 16, 1954, the study plot was larvicided. The application was done by hand using a three gallon Hudson pressure spray can. A favorable wind aided the application, and the entire area of the check was successfully covered.

Six gallons of 2% water emulsion DDT spray were applied in the treatment. Thus, the application rate was approximately 4 lbs. of actual DDT per acre. This excessive treatment was applied to insure a kill of both mosquitoes and the hardiest of predator species.

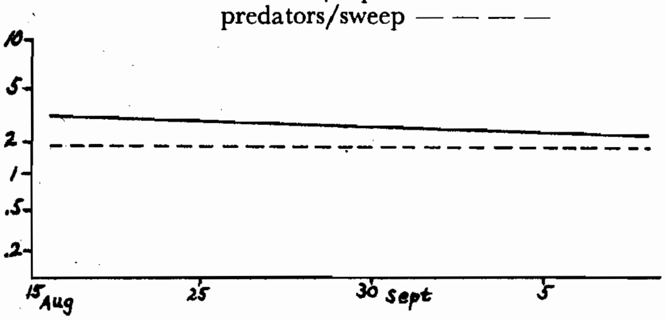
RESULTS: The mosquito population of the study plot on the day previous to the treatment was 2.6 per dip. Invertebrate predators averaged .5 per sweep before the treatment.

Population determinations on the day following the treatment revealed that the treatment was successful in killing all mosquito larvae and all invertebrate predators in the test plot. Both remained absent during the ensuing week. Eight days following the treatment, specimens of first instar mosquito larvae (*Culex tarsalis* Coq.) and adult Notonectidae were collected from the study plot.

The mosquito population recovered rapidly after the eighth day. Two distinct broods of *Culex tarsalis* emerged within 15 days. The numbers of larvae collected by dipping averaged 3.5 per dip during the larval stages of the first brood and 7.5 per dip for the second brood. The 15 day average for these two broods was 5.4 per dip. A few first instar *Anopheles* (presumably *freeborni*) were collected during the test period, but they were extremely scarce.

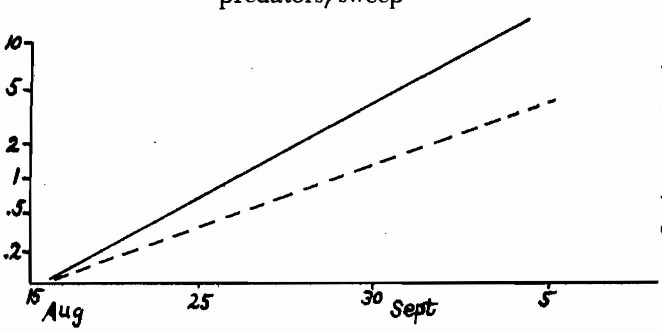
Insecticide - Predator Study. Gerhardt, 1954
Rice Field Mosquito Ecology Project
Control (untreated) Plot
semi-logrithmic

larvae/dip———
predators/sweep — — — —



Experimental (treated) Plot
semi-logrithmic

larvae/dip———
predators/sweep — — — —



The predator population in the study check recovered simultaneously with the mosquitoes, but to a lesser extent. The average number collected per net sweep during the 15 day period previously mentioned was 1.1.

The composition of the predator population changed following the treatment. Adults of Notonectidae were first to re-enter the study check. A few adults of Dytiscidae were noted 12 days after the treatment, but their numbers remained low. No naiads of Odonata were found in the test plot after the treatment.

During the test period, the population levels of larvae and predators in the control (untreated) plot remained approximately parallel. The average number of larvae collected during the test period was 2.4 per dip, while the predators averaged 1.8 per sweep.

The accompanying graphs illustrate, comparatively, the populations of larvae and predators in the two plots.

CONCLUSIONS: Unfortunately, it was possible to conduct only one experiment of this type during the rice growing season of 1954.

On the basis of the data available it is suggested that a single larvicidal application may do more damage than good by reducing natural predators of mosquito larvae. Ecological experiments of this type need to be repeated in such a manner as to yield information on the effects of insecticides as they are normally applied in abatement work.

Additional work of this type is planned, and it is hoped that further information on this subject can be presented at future mosquito control conferences.

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RESTING HABITS OF ADULT *CULEX TARSALIS* COQUILLETT IN SAN JOAQUIN COUNTY, CALIFORNIA, NOVEMBER, 1953 THROUGH NOVEMBER, 1954. A PRELIMINARY REPORT[1]

E. C. LOOMIS[2] AND D. H. GREEN[3]

INTRODUCTION:

This study continues investigations begun by Mortenson (1953) in the winter of 1952-1953 in Fresno and Kings Counties, California, on the overwintering behavior of adult *C. tarsalis*. The present investigation was expanded in scope to include the following aspects of the biology of this species: natural resting places selected during both the winter and summer months; the use of both natural and artificial resting places by the overwintering population; and observations on gravid and engorged conditions of females during the overwintering period.

PROCEDURE:

Bi-weekly surveys were made from nine natural and from 12 to 15 artificial resting places within a non-controlled mosquito area of San Joaquin County, continuously from November, 1953. The natural resting places consisted of animal burrows, tree stumps, and uprooted ends of fallen trees. The artificial resting places consisted of chicken houses, bridges, and cellars. With the exception of two surveys, all collections were made by one person. Each resting place was inspected for approximately five minutes and at the same time of day in each survey. The collection procedure in the natural resting places was the same as used by Mortenson (1953). In using this method the collector covered himself with mosquito netting and took a position so that the mosquitoes leaving the resting place would land within the net. By spraying three charges of chloroform from a flit gun into the entrance of the resting place, the mosquitoes were activated and collected from the net by means of an aspirator. Ten-minute col-

[1]Conducted by the Bureau of Vector Control, California State Department of Public Health.
[2]Associate Vector Control Specialist, Bureau of Vector Control.
[3]Vector Control Officer, Bureau of Vector Control.

lections from artificial resting places were made with an aspirator.

RESULTS:

C. tarsalis was found to use the natural resting places throughout the year (Figure 1). During the colder months, December through February (air temperatures below 50 degrees), this species constituted 73 percent of the female mosquitoes recovered from these resting places (see Table I). During the warmer months, May through November (air temperatures from 67 to 81 degrees), this species constituted 42 percent of the total female mosquitoes recovered from the same resting places. The results of the 1952-53 study by Mortenson indicated that trees and brush piles were better collecting places than animal burrows for *C. tarsalis*. The present 15-month study showed no significant preference by this species for either animal burrows or tree-resting places. It is interesting to note that almost all mosquitoes disappeared from trees from March 3 to March 31 and from animal burrows from March 17 through April 12.

Recoveries of female *C. tarsalis* from artificial resting places during the same cold and warm months of the year amounted to 13 and 34 percent, respectively. There is, therefore, an indication of preference by this species for natural resting places during the winter months.

Engorged and gravid *C. tarsalis* were first found in the natural and artificial resting places on February 17 and March 3, 1954, respectively. This closely follows the recoveries in January and February of fed and gravid *C. tarsalis* from Kern County by Brookman (1950) and Kings and Fresno Counties by Mortenson (1953). The percent of engorged and gravid specimens recovered from these different resting places probably is not significant because of the low number of specimens recovered. In comparison, engorged and gravid *Culex pipiens* were found every month except February in artificial resting places and every month except December, January, and February in natural resting places. Engorged but never gravid specimens of *Anopheles freeborni* were recovered throughout the winter months (November to March) in artificial resting places; whereas, this species was never recovered in natural resting places during these same months.

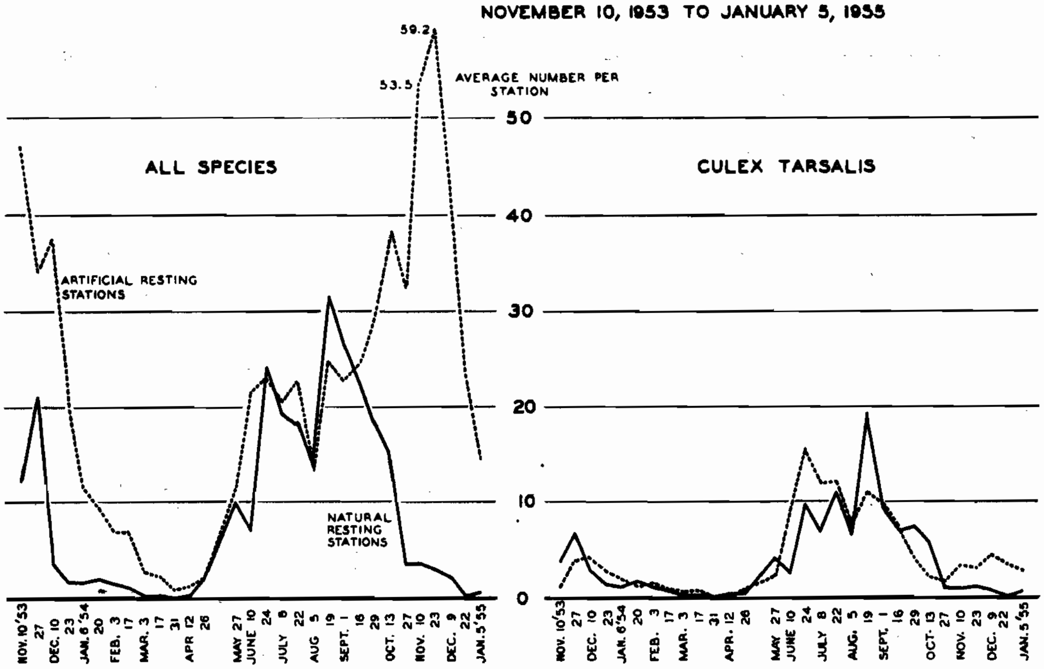
The various species in the natural resting places to date show three dominant mosquitoes in order of their frequency of occurrence: *C. tarsalis, C. stigmatosoma,* and *C. pipiens.* Eight other species amounted to only three percent of the total species recovered and are, in order of their frequency of occurrence: *Aedes varipalpus, Aedes dorsalis, Anopheles freeborni, Culiseta inornata, Culiseta incidens* and *Anopheles punctipennis, Culex erythrothorax* and *Anopheles franciscanus.*

The results obtained from the present 15-month investigation indicate a trend of the behavior pattern of

TABLE 1. RECOVERIES OF FEMALE MOSQUITOES FROM SAN JOAQUIN COUNTY CALIFORNIA, NOVEMBER 1953 THROUGH JANUARY 5, 1955

DATE COLLECTED	ARTIFICIAL RESTING STATIONS					NATURAL RESTING STATIONS				
	Number of stations collected	Total female mosq.	Total female C. tarsalis	No. of female mosq./ station	No. of female C. tarsalis/ station	Number of stations collected	Total female mosq.	Total female C. tarsalis	No. of female mosq./ station	No. of female C. tarsalis/ station
November 10, 1953	12	566	12	47.1	1.0	9	109	34	12.1	3.7
November 27	12	411	46	34.2	3.8	9	188	61	20.9	6.7
December 10	14	523	58	37.4	4.1	9	34	26	3.7	2.9
December 23	15	301	40	20.0	2.6	9	13	11	1.4	1.2
January 6, 1954	14	164	26	11.7	1.9	9	16	9	1.7	1.0
January 20	15	142	16	9.4	1.1	9	17	13	1.9	1.4
February 3	15	103	23	6.9	1.5	9	12	9	1.3	1.0
February 17	15	101	13	6.8	0.8	9	9	6	1.0	0.6
March 3	14	40	6	2.8	0.4	9	1	1	0.1	0.1
March 17	13	29	9	2.2	0.7	8	2	1	0.2	0.1
March 31	15	14	0	0.9	0.0	9	0	0	0	0
April 12	14	17	3	1.2	0.2	9	3	3	0.3	0.3
April 26	15	31	9	2.1	0.6	9	18	4	2.0	0.4
May 27	14	166	29	11.8	2.1	9	89	36	9.9	4.0
June 10	14	302	125	21.5	8.9	8	56	19	7.0	2.3
June 24	15	346	230	23.1	15.3	9	215	88	23.9	9.7
July 8	15	307	177	20.5	11.8	9	172	62	19.2	6.9
July 22	15	341	180	22.8	12.0	9	162	98	18.0	10.9
August 5	15	198	111	13.2	7.4	9	122	58	13.6	6.4
August 19	14	345	153	24.6	10.9	8	252	154	31.5	19.2
September 1	15	340	142	22.6	9.5	9	236	83	26.2	9.2
September 16	12	292	87	24.3	7.2	9	200	62	22.2	6.9
September 29	15	437	59	29.1	3.9	9	163	65	18.1	7.2
October 13	14	534	28	38.1	2.0	9	136	50	15.1	5.5
October 27	14	454	21	32.4	1.5	9	31	9	3.4	1.0
November 10	14	750	45	53.5	3.2	9	31	8	3.4	0.8
November 23	13	770	39	59.2	3.0	9	27	9	3.0	1.0
December 9	14	594	59	42.4	4.2	9	18	7	2.0	0.7
December 22	15	432	47	28.8	3.1	9	0	0	0	0
January 5, 1955	15	216	42	14.4	2.8	9	4	4	0.4	0.4

RECOVERIES OF FEMALE MOSQUITOES FROM SAN JOAQUIN COUNTY, CALIFORNIA
NOVEMBER 10, 1953 TO JANUARY 5, 1955



C. tarsalis. Additional information may be contradictory. For example, collections made from the natural resting places in November, December, and January, 1954-1955 show a four-fold decrease of *all* mosquito species when compared with collections made during similar months in 1953-1954. An increase in all mosquito species is observed when collections from artificial resting places are compared for these same months during the two winter periods. A contributing factor to these differences may be the extremely low air temperatures recorded during these three winter months of 1954-1955 in the natural resting places.

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SUMMARY OF THE COASTAL REGION'S MOSQUITO CONTROL ACTIVITIES FOR 1953-54

William L. Rusconi, *Superintendent*
Napa County Mosquito Abatement District

In the beautiful sunlight of the San Francisco bay region there are nine (9) Mosquito Abatement Districts. When individuals are talking about mosquito control problems in the bay region M.A.D.'s, they are usually discussing the salt marsh mosquitoes, *(Aedes squamiger, Aedes dorsalis)* and the problems of control relating to those mosquitoes. Hardly any mention is made to the fresh water species, (*Culex tarsalis, C. stigmatosoma, C. pipiens,* etc.) and their control problems. However, it is of interest to note that practically all representatives of the M.A.D.'s with whom I spoke or who forwarded a summary of activities for the 1953-54 mosquito breeding season stated quite clearly that more than half of their annual expenditures were used for the control of the fresh water species. The questions now arise as to what happened to the salt marsh mosquitoes to make them practically disappear from our salt marshes, and to the whys and wherefors of such large expenditures for the control of the fresh water mosquitoes. The consensus of opinion among all the Bay Area M.A.D.'s concerning the answer to the first part of the question is that source reduction through drainage practices, reclamation of many marshes by dirt filling, and by properly timed remedial spray operations have reduced salt marsh mosquito breeding. In answering the second part, all agreed that a tremendous increase in industrial plants, suburban housing, and consequently greater water use have caused an increase in mosquito breeding sources, such sources including oxidation ponds from cannerys, sewage disposal ponds from newly incorporated areas, an increase in catch basins, storm and domestic drains, fish ponds, and extensive irrigated agriculture in some districts (Solano, Santa Clara, Contra Costa, and Alameda).

All the bay area districts indicated that they had enjoyed an exceptionally mosquito free year. Three districts (Contra Costa, Napa, and Solano) reported increasing annoyance with muskrats that burrow adjacent to the tidegates and thus cause damage by flooding many acres of mosquito breeding ground. Several M.A.D.'s (Marin, Alameda, San Mateo, Contra Costa, and Lake) are experimenting with some of the newer insecticides for more efficient control. One district (Marin) has built two new, one-man operated mist blowers as spray rigs, and three districts have made copies of them for their own use.

As for source reduction and drainage practices all the abatement agencies in the bay region are emphasizing and constantly carrying on this type of program. One district (Solano) has added another thirteen (13) miles of Soil Conservation Service drainage ditch to one area in its county.

The bay area's Mosquito Abatement Districts meet frequently as members of a Mutual Admiration Society, or at least a group so termed by some of the districts in the bay region. To this organization all of the nine bay region M.A.D.'s are members. There is no president, vice-president, or secretary to this society, only the regional representative, who is the work-horse of the group. The one and only policy of the organization is to promote mutual cooperation on problems, projects, studies, etc., dealing with mosquito control in the bay region. This society first came into being many years ago when certain District managers in the area were called together at Harold F. Gray's request to discuss mosquito problems on a regional level. Thereafter the bay area districts, through their society, have cooperated in conducting a Flight Range Study (on *Aedes squamiger*), an annual regional training or school session, and an annual regional meeting of managers, entomologists, and foremen, and have fostered individual cooperation in mosquito problems between neighboring districts and themselves. So, Harold F. Gray, we in all of the Bay Regions' Districts wish to thank you whole heartedly for the founding of our society for the cooperation of our mosquito abatement districts.

SACRAMENTO VALLEY REGIONAL REPORT

Ernest E. Lusk, *Administrator-Entomologist*
Los Molinos Mosquito Abatement District

In reviewing some of the reports of past years covering mosquito control in the various districts of the Sacramento Valley, there are two things that are noteworthy each year. One is that each year is an unusual one, and the other is that no one has ever considered the year's efforts to be a failure. On the contrary, although we all suffer occasional reverses when we may have a little trouble accounting for our mosquito population, we generally end up the year with a feeling of accomplishment. We know that we have killed a few mosquitoes, and we hope that we have found opportunity to insure that next year there won't be quite as many places for them to breed as there were during the past season. This year has not proven to be an exception to that rule.

All due respect is given to the weather conditions as they prevailed during the past year, which most of the districts feel were partially responsible for the success of the past year's operations. However, we must also give credit to the men who are on the job and trying each year to do a better job of control. Nw techniques, new materials, and new equipment are employed each year to give better results.

As an example: Bob Portman in Butte County and Dick Sperbeck in Sutter-Yuba District report that the increased use and efficiency of plane spraying in their areas contributed greatly to the success of their operations.

Joe Willis in Shasta County has been using a new Cat bulldozer to fill in some of his heavy breeding sources and attributes much of last season's success to the elimination of these heavily producing areas.

New techniques of control of breeding in the olive vats in the Corning District have in some cases nearly eliminated these formerly major sources of *Culex tarsalis.*

Rather than try to present any of the details of operations in the Sacramento Valley I will present reports from the various districts for inclusion in the Proceedings of this meeting.

LOS MOLINOS MOSQUITO ABATEMENT DISTRICT AND CORNING MOSQUITO ABATEMENT DISTRICT SUMMARY OF ACTIVITIES — 1954

Ernest E. Lusk

Control operations in both districts progressed satisfactorily during the past year.

Considerably less trouble was experienced from mosquito breeding in the olive packing plants in the Corning area during the past year as compared with the previous season. Much of the credit here is due to the industry in that they were very cooperative in executing measures designed to reduce the problem. One plant adopted a system of covering their outside vats, which completely eliminated any breeding and reduced the district's problem to a minor one of periodic inspection and treatment of drains from the tanks. Chemical control as employed by the other plants gave very satisfactory results.

Both the Corning District and the Los Molinos District are fortunate in being located within the boundaries of Soil Conservation Districts. Excellent cooperation between the two agencies is obtained in the source reduction and eliminative programs. During the past year several cooperative projects involving the Soil Conservation and Mosquito Abatement Districts and landowners have been completed.

Larviciding operations were commenced during the last part of February but were on a limited scale only through March. Scattered instances of resistance to insecticides were apparently encountered. DDT continued to be effective in the Corning area. Some resistance to DDT and Toxaphane was noted in the Los Molinos district, but excellent results were obtained with Malathion although the lack of residual action was noticed. A small amount of DDT-Dieldrin granulated material was used in several instances in the Los Molinos area with satisfactory results on *Aedes* larvae. Excellent results were obtained with 2,4,5-T brush killer in killing wild blackberries along several sloughs in the Los Molinos district.

Four light traps were operated in the two districts and provided us with a great deal of information regarding the adult mosquito occurrence in their respective areas. Although the traps are located several miles apart, charts of the catches obtained from each are very similar, showing peak populations for the season at nearly the same dates, i.e., the middle of July.

Larval sampling methods are still in need of improvement, but they did give us considerable information on breeding intensity and reinfestation rates.

SUTTER-YUBA MOSQUITO ABATEMENT DISTRICT SUMMARY OF ACTIVITIES — 1954

Thomas M. Sperbeck, *Manager*

With due respect to weather we had our best year in many respects—fewer complaints and more satisfactory results. For example, our total number of calls in 1953 was 967; the 1954 total was 278. In our hottest month (July) we had 120 calls this year as contrasted with 368 the year before and 41 in September compared with 242 the previous September.

To partly account for results, we had more success this last year with the plane, particularly on pastures; but we also used the plane for floodwater control, for *Culex* and

Aedes in rice fields, and for miscellaneous *Culex* sources. Because of economic limitations, we picked out only certain large pastures for airplane control, the choice based on the source's proximity to centers of population or the degree of aid in speeding up control by means of relieving an operator for a major part of his time.

The plane put 193 loads on 9,053 acres at an average cost of $1.10 per acre; but costs ranged from $0.59 to $5.68 per acre, depending upon the problem. The application rate was modified as the season progressed to 3 gallons per acre with a DDT-Dieldrin combination; the dieldrin rate was approximately 0.1 pound per acre.

1954 ACTIVITY HIGHLIGHTS BUTTE COUNTY MOSQUITO ABATEMENT DISTRICT

ROBERT F. PORTMAN, *Manager-Entomologist*

THE DISTRICT had a good control season due to the following factors:

a. Increased zones of control.
b. More efficient field crews.
c. Increased larviciding and adulticiding by plane spray.
d. Increased cooperation by individuals and agencies.
e. Cooler weather had some general effect on the length of the life cycles and the intensity of breeding.
f. Resistance to insecticides not general enough to constitute a major problem.

THE FOLLOWING DETERRENTS to control were encountered during the year:

a. Aerosolling conditions were generally fair to poor and usually of short duration.
b. General, overall increase of prevalence of *Culex tarsalis*, with high to very high infestations in a few rice fields.
c. Spotted, high resistance to some insecticides.
d. Increase of marginal lands planted to ladino pasture with little drainage provided.
e. Winds during the first part of the season prevented effective plane spraying on same occasions.

AEROSOLS:

The District's standard DDT aerosol formulation is still effective under good to excellent aerosolling—atmospheric conditions on *Aedes* and *Culex* species including *Culex tarsalis*. Benzene hexachloride aerosol formulations were not much more effective than DDT formulations.

INSECTICIDES:

a. DDT oil based larvicides are still effective.
b. DDT and Rothane water emulsions are still effective, although in general are less effective than oil based sprays.
c. Heptachlor water emulsion larvicides are effective, on *Aedes* larvae—with little effect on *Culex tarsalis* larvae.
d. Dieldrin water emulsion larvicides are very effective on *Aedes* larvae but have little effect on *Culex* larvae. Several instances of what appeared to be complete resistance by *Aedes* larvae were encountered in one instance where Dieldrin had not been used before.
e. Malathion was very effective on *Aedes* and *Culex* larvae although it lacks the residual effect on Dieldrin.
f. Benzene hexachloride formulations effectiveness did not warrant continued use.
g. Lethane 384 continued to be an effective supplemental insecticide when used in larvicide and aerosol formulations.
h. Plane spray adulticides were effective in the following order: Dieldrin, Malathion, Heptachlor, DDT.
i. Richfield Weed Killer A was an effective larvicide for breeding in waters containing a high amount of organic matter, i.e., sewage effluent, logging ponds, etc. It was an effective larvicide and pupicide used straight and slightly less effective as an emulsion. It was an effective general herbicide.
j. Insecticide impregnated granules as larvicides were effective and useful under certain circumstances, particularly in dense vegetation.

MOSQUITOES:

a. *Culex tarsalis* has become one of the most prevalent pest mosquitoes throughout the District, rivaling other seasoned species. It has surpassed *Anopheles freeborni* in some rice fields, and was found in great numbers in several. In one rice field it supplanted *Culex stigmatosoma* in the spring, built up to great numbers and resisted intensive measures to control it.
b. *Aedes nigromaculis* has replaced *Aedes dorsalis* as the dominant pasture species in the southern portion of the county, and is becoming more prevalent in the northern portion.
c. *Anopheles freeborni* was not as generally prevalent in the rice fields as in former years. The rather light infestation during the summer increased rapidly during the early fall and built up to considerable numbers due to the extended rice growing season.
d. *Aedes varipalpus*—hatched with the first rains in October and November. The heavy rainfall in the fall has been very favorable for their breeding.
e. *Orthopodomyia californica*; a few adults were caught in a Chico light trap; in the winter one hole in a white oak near Bangor was found to contain large numbers of the larvae.
f. *Culex erythrothorax* was found in considerable numbers in a fresh water, wooded slough, where the adults would readily bite man.

NOTES ON MOSQUITO MEASUREMENT METHODS:

Adults: Fourteen light traps:

a. Gave a daily and seasonal picture of adult intensity in areas where traps are located.
b. Indicated areas needing adulticiding before service requests were received.
c. Sampled species in the areas where traps are located thus indicating nearby sources.
d. Do not sample enough of the total area.
e. Are not satisfactory in sampling winter mosquito populations.

Twenty-six Adult collecting stations:

a. Gave weekly and seasonal adult intensity in areas near stations.
b. Most accurate in sampling over wintering species.
c. Provides year by year intensity (adult) comparisons.
d. Does not give daily picture of adult intensity.
e. Collecting and estimating methods are not accurate.

Larvae—Forty-five fixed larval stations:

a. Gave early warnings of breeding rate increases.
b. Indicated the breeding intensity of some species in different types of source habitats.
c. Indicated reinfestation rate of certain species in different types of source habitats.

d. Gave only general indications of species and breeding intensities because of the small amount of area represented.

f. Similar sources have many differences.

g. Were set up primarily in places which were potential breeding sites for *Culex tarsalis* and thus did not measure or give an accurate picture of the other species.

MOSQUITO CONTROL HIGHLIGHTS IN THE SHASTA MOSQUITO ABATEMENT DISTRICT FOR 1954

J. D. Willis, *Manager*
Redding, California

The year 1954 was very unusual in many ways for the Shasta Mosquito Abatement District. During the previous year, 1953, we had a great deal of trouble with the *tarsalis* mosquito and several serious outbreaks of *Aedes nigromaculis*. We had expected that we would have this trouble again in 1954 and attempted to plan our program accordingly.

The larviciding season of 1954 has now passed, and we can see why this did not occur. Areas that created serious outbreaks of *Aedes* in 1953 were watched very closely as the season progressed in 1954. We could definitely see where our eliminative and drainage program, which was started in the fall of 1953 (after the purchase of a D-4 Caterpillar tractor) and carried on throughout the winter into 1954, paid dividends. In many places serious mosquito breeding areas were completely eliminated and in many other places cut to a minimum by partially filling or opening of the drains.

Probably the most important factor helping us in 1954 was the unusual weather conditions throughout the year, which seemed to keep the mosquitoes from having a big build-up at any one time.

It was necessary to start limited larviciding activities along with the routine premise inspection by the first of February. Most of the larviciding at this time was on either septic tanks or open septic tank drains. By the end of February it was necessary for the operators to larvicide where they were finding *Culiseta* larvae in lakes formed by winter rains. In March we had a complete reversal of weather conditions, with two inches of snow on the 15th. Although in April we had some very hot weather, with temperatures in the high 90's, conditions thereafter remained normal until mid-summer.

About the middle of August, we had our most unusual weather, with 2½ inches of rain. This seemed to completely break the mosquito build-up in our District. Our most severe annoyance in 1953 was during August, when we received 58 service requests. During August of 1954, we received only 16. There was a total of 53 service requests in 1954, as compared to 104 service requests in 1953.

As a part of our eliminative program, which we have mentioned previously, we have been able to work into a mutual cooperative program with the Irrigation District, whereby we use our D-4 Caterpillar, and they use their dragline on the same projects. This is a very satisfactory arrangement, and we are hoping to expand it in future years. We are also getting closer cooperation from the County Road Department, whereby they are cleaning their road drains where these are a part of our master drainage system.

In August of 1954 we had a very serious problem caused by a pond in one of the larger lumber mills, and from August 6 to November we spent over $600.00 on the one pond alone. After meeting with the officials of this firm, they have agreed to furnish all labor to do larviciding on their pond in the future, and to do whatever we should recommend to cut down the mosquito breeding in the pond.

Our individual index system of cost of labor and materials on each mosquito producing property has probably become our most valuable weapon to obtain cooperation from the landowner. Most of the mosquito producers do not realize what it has been costing the mosquito abatement district for control on their property.

Another advancement in our district which will be of great help in the future to us was the formation of a complete County Health Department, which has pledged to do everything they can to eliminate the more serious problems caused by septic tanks in our district. Because of poor drainage conditions in the district, septic tanks or their drains have been a very considerable source of *Culex tarsalis*. During the past season, it was necessary to larvicide 3,486 septic tanks or open septic tank drains.

The first of March we started operating three light traps, which were operated through October. I believe these are the first light traps ever used in this area. We have always used adult collection stations for adult collections in the past. The use of light traps has confirmed our findings of the past few years, that *Culex tarsalis* is the most prevelant mosquito in the district. 68% of the adults collected in 1953 from the collection stations, were *C. tarsalis*. 93% of the adults collected in the light traps in 1954 were *C. tarsalis*.

SAN JOAQUIN VALLEY REGIONAL REPORT

Gordon F. Smith, *Technical Director*
Kern Mosquito Abatement District

I sent out a bunch of letters to the boys in the valley and had exactly two replies. I think that our major progress in the valley this year can be summed up in two items; first, the increased use of the phosphate insecticides due to the mosquito resistance to the whole chlorinated hydrocarbon family. Quite a large number of districts in the valley this year have had to use it. Because of the considerable fears in the past in using these materials, the highly toxic phosphates, EPN, Malathion, and Parathion accounted for the greatest phosphate use in the Valley. Of course, Malathion is safe to use, but is quite expensive. An impressive amount of Parathion, considering the one total insecticide use, was applied. I have not heard of any case of poisoning through the use of Parathion. It is useful, but proper precautions must be adhered to.

The second major advancement in the valley, I believe, is in the considerable increase in and effort toward source reduction. It has become not only advisable but absolutely necessary because of the insecticide difficulties. Much more effort is being put into this work than there has been in the past.

The second letter I got was from Marvin Kramer. He has developed a very interesting pump to be driven off a jeep pick-up truck power-take-off; so, I'll let Marv tell you about it.

SAN JOAQUIN VALLEY REGIONAL REPORTS THE "BARLOW BOOSTER" LOW LIFT PORTABLE SUBMERSIBLE PUMP

Marvin A. Kramer, *Manager*
Tulare Mosquito Abatement District

In the Tulare Mosquito Abatement District we had found, all too frequently, that there were situations in which an excess amount of water was standing, and in which there would be multiple benefits resulting from its removal. In most of these cases, that removal could be effected by means of a portable pump.

In order to demonstrate the benefits that would accrue from removal of this excess water, the District decided to buy a portable pump.

We consider ourselves fortunate in having had a new idea in pumps brought to our attention by its inventor, Art Barlow, of the Tulare Irrigation District.

The pump is essentially a long, metal tube, 10 inches in diameter. It is hydraulic, submersible, propeller-driven, and completely portable. Ours is carried on a Willys pick-up. An Hydreco pump on the power take-off of the pick-up operates the propeller in the pipe by circulating oil through two neoprene hoses that carry the oil to the propeller and then back to the Hydreco pump.

The 4-wheel drive pick-up will take the pump practically anywhere. We place the end of the tube into the water to be pumped, shift the power-take-off into gear, set the motor at slightly more than idling speed, and the pump keeps a steady, 10-inch stream of water flowing.

The pump was designed originally for tractors, and has been used successfully on a number of them. It is beautifully adaptable, and requires only that the specifications be correct for the type of vehicle that will power it.

Mr. Barlow says this about the pump: "The pump was designed with these factors in mind, namely, a low priced unit that would be extremely portable, easily maintained, flexibly powered and, of course, efficient in operation.

"To date, three sized pumps have been manufactured: twelve inch, ten inch, and eight inch. All have discharge pipes twelve feet in length. The pumps are priced at—

12 inch	$325.00
10 inch	$305.00
8 inch	$275.00

Each bears a thirty-day guarantee.

"The units are limited in design, to enable two men to carry and set even the large size. The straight discharge adapts itself very well to low lift settings and can be easily extended for special pumping jobs. The fabricated steel assembly takes the shocks and bumps of portable handling with no ill effects and can even be pulled free of the setting by a vehicle after a job is completed.

"Hydraulic power is a simple, efficient coupling, and with a minimum of care gives many hours of trouble-free operations. The submersible characteristics of this unique pump eliminates practically all shafting, shaft bushings, stuffing boxes, universal joints, etc. found in the controversial portable pumps.

"Hydraulic hoses are the only connection between the pump and the power unit, which makes positioning the unit a snap under practically any conditions.

"When supplied with the recommended volume of oil at proper pressure, each size of pump gives good account of itself in gallons of water delivered. At average heads, the twelve inch pump will lift up to 3500 gallons per minute; the ten inch unit, up to 2000; and the eight inch, up to 1600 gallons."

Believe it or not, I have no monetary interest in these pumps and I will receive no commission or other benefit from their sale. I'm just passing along the information because the pump has worked so well for us, and I felt you might be interested.

Mr. Kimball: Thank you, Mr. Kramer and Mr. Smith. I think the reason the three confrerate regions in California are so embarrassed to talk more than 3 minutes in this Southern California meeting place probably goes back to the last meeting in Berkeley—all the blabber mouths up there took up all the time so that our regional representative was reduced to give his report by presenting the addresses down here as P. O. Box 87, etc.; if you will remember Norm Ehmann's statement. Since it is now only 10:05, we have until 10:50. I'd like to call on Mr. McFarland, Manager of Southeast Mosquito Abatement District, to present a long dissertation on our Southern California operations. Mac, you have 45 minutes. (laughter)

Mr. McFarland: I think we should have an hour and 35 minutes for you will remember from last year the south was given 35 seconds. We don't even need 35 minutes actually.

SOUTHERN CALIFORNIA REGIONAL REPORTS SUMMARY OF ACTIVITIES OF THE SOUTHEAST MOSQUITO ABATEMENT DISTRICT, 1954

Gardner C. McFarland, *Manager*

The activities of this relatively new District (in its third year) are becoming more routine. The source reduction program of the District is well-organized and coordinated with the activities of other closely related agencies. The Corps of Engineers, Flood Control, and various other agencies have cooperated closely with the District to the end that mosquito sources caused by those agencies have been much reduced.

Very close working arrangements have been made with adjoining groups such as the Orange County Mosquito Abatement District, the Agricultural Commissioners, and Orange County Flood Control so that mutual problems of mosquito breeding have been satisfactorily solved.

The District took a long step in the public information field by producing an information pamphlet to be distributed to interested groups and citizens of the District. It is felt that this pamphlet will help immeasurably in informing the public and in gaining their continued and improved cooperation.

As is true of all districts in the southern region and other mosquito abatement groups, the emphasis has been in source reduction and in reduction of sources by the individuals responsible. In this respect, the dairy industry (over 400 dairies) has been very successful in the abatement of mass sources of breeding. Close coordination has been effected with planning commissions to the end that subdivision activity can be carried out without the creation of innumerable new breeding sources.

SUMMARY OF ACTIVITIES FOR 1954 OF THE BALLONA CREEK MOSQUITO ABATEMENT DISTRICT

NORMAN F. HAURET, *Manager*

The activities of the District for the year 1954 have been in the execution of a long range program. The emphasis in the program has been placed upon "Source Reduction" through the construction and maintenance of dykes and ditches and installing new tide gates and repairing old ones.

For the first time in many years, mosquito breeding was encountered in water meter boxes. These boxes were sprayed with oil and DDT, which proved to be effective, but was time-consuming.

The District has continued to encourage industry to control those sources of mosquito breeding which they create. Often, the control measures used by industry are those suggested by the District.

Where other governmental agencies have responsibilities that aid in mosquito control, every effort is made to have that agency fulfill those responsibilities.

SUMMARY OF ACTIVITIES COACHELLA VALLEY MOSQUITO ABATEMENT DISTRICT

ROBERT E. WINTER, *Manager*

Coachella Valley District has no mosquito problems—just man problems. And since man is in the Valley to stay, and immigrating rather rapidly, our problems are here to stay.

Crops valued at more than 24,000,000 dollars were harvested from agricultural lands in Coachella Valley this last year, and a recent survey shows 54,109 acres under cultivation. With over 30,000 of these acres planted to field crops, waste- tail- or runoff-water (as you wish) is the biggest problem we have. Water is cheap, so the first economy a farmer or rancher effects in a bad year is to lay off his irrigator. Thus the borrow ditches get filled and don't drain; the tules and salt cedar grow prolifically; and the Coachella Valley District goes to work to control the mosquitoes.

My association with this District began July 1, 1954, as Manager. By July 15th I was in a ditch in the middle of a 90 acre swamp, helping to plant self-propagating ditching dynamite sticks, 12 inches apart for one mile. This swamp was man-made about two years before and had been one of our major sources of both *Psorophora* and *Culex tarsalis* mosquitoes. Treatment of the area was virtually impossible even by plane because of the dense growth of tules, salt cedar and mesquite. The dynamite did the job! In three weeks the swamp had drained and the ditch was carrying off the waste water into the Water District waste-way canal to the Salton Sea. When soil samples showed dry enough to risk a grader, the County Road Department scraped an access road beside the ditch, and we can now maintain it at minimum expense.

Thermal Airport sewage disposal system was a close second on the headache list. This airport was a training station for the Air Corps during the war, and hundreds of recruits lived there. An Imhoff Tank theoretically took care of the sewage with ponds handling the overflow. With the war ended, the Air Corps moved out and the Imhoff tank gradually quit functioning. The ponds became overgrown with assorted weeds. However, the airport still operated and fed the lines as did the Elementary School and a grape-packing shed. The lines leaked all over the desert and we had more mosquito sources. Persistence (saddle burr under the blanket type) resulted in the County Airport Commission authorizing construction of a septic tank—work to start next week.

The installation of float valves in water troughs in date gardens where cattle are being kept has minimized another of our sources. No one garden a major problem; but collectively, impressive.

The capping of eight artesian wells, mainly in the Salton Sea area, which previously ran unchecked, eliminated another of our time-consuming sources.

Another area covering 6 miles of borrow ditches on both sides of County roads was dried up for the first time in six years through cooperation of the farmers, thus permitting the Road Department's heavy equipment to get in and clean and improve these ditches where some of our best specimens were collected.

The other half of our activities involves attempts to control the "eye gnat" (responsible for the Indio salute). Larviciding with Aldrin spray at rates of 2 pounds per acre for row crops and 3 pounds per acre for dates and citrus is more than promising as an effective control for a two-year period. We don't know yet whether or not lower concentrations may be used as effectively. Our laboratory staff is conducting micro-bio-assay experiments to determine the lethal dosage required. Through the courtesy of the University of California at Riverside, some of their equipment is being utilized for the present.

Chemical analysis of soil samples is being performed by Shell Oil in Denver as a desirable adjunct to the bio-assay.

Experimentation in methods for raising gnats is another facet of our research program.

This year more than 5,000 acres will be treated with Aldrin. In addition, 38 experimental plots on 10 different ranches will be treated with Aldrin and Heptachlor in amounts from 1 to 4 pounds per acre. Arochlor will also be used in combination with Aldrin to determine the ability of this extender to prolong the effectiveness of this chemical.

MOSQUITO CONTROL ACTIVITIES OF THE LOS ANGELES HEALTH DEPARTMENT FOR THE YEAR 1954

JOHN RUDDOCK, *Entomologist*
EARLE W. DUCLUS, *Supervisor of Field Operations*

During the year 1954 the city of Los Angeles was divided into five separate zones of which each zone was treated by a vehicle equipped with a 60-gallon Essick sprayer and a motorcycle equipped with a twenty-gallon Essick sprayer for the purpose of treating inaccessible areas which could not be reached and treated by larger vehicles, and for spraying gutter water which is the main source of mosquitoes in Los Angeles city.

There were 75,000 mosquito fish *(Gambusia affinis)* planted in various areas throughout the city such as sloughs, lakes, creeks, etc., plus approximately 17,000 mosquito fish which were distributed to the public for use in private pools and ponds for the control of mosquito larvae.

Through the medium of radio and television and by distributing some 2,000 pamphlets, people in some areas have become more mosquito-conscious and have helped allay our mosquito problems greatly.

During the current year we have received approximately nine hundred mosquito complaints from private citizens. If the habitat is on private property, the people concerned are educated as to how to eliminate or control the problem. The areas sprayed on public property are treated with a 5% DDT or a 5% DDD water emulsion. Diesel oil was also another effective larvicide.

Breeding problems which could not be eliminated by spraying were referred to the Sanitary Engineering Department, to other city departments, and to government agencies for further consideration.

In the city we have approximately three hundred private habitats (habitats not on public property), five hundred and fifty active habitats, ninety-five habitats where larvae are controlled by fish, and one hundred and fifty habitats in unimproved housing tracts. Counting all types of habitats the city has approximately 1,125 breeding sites. This year there has been a steady increase in the number of new tracts in the city which cause new habitats due to the grading and filling of certain areas.

Three light traps were run from April to October in the San Fernando Valley, and in conjunction with this adult collections of *Culex tarsalis* mosquitoes were made and sent to the laboratory to determine whether or not the Encephalitis virus is present.

In 1954 approximately 13,000,000 square feet of gutter water, swamps, ditches, etc. were treated, using five hundred gallons Diesel oil, 4,000 gallons of 5% DDT and two hundred galons 5% DDD.

1954 HIGHLIGHTS OF THE ORANGE COUNTY MOSQUITO ABATEMENT DISTRICT

JACK H. KIMBALL, *District Manager*

Policy and procedures on the abatement of mosquito breeding sources formulated over the past several years, were crystallized during 1954 by written notification to persons responsible for 20 major sources and by formal action against one large dairy farm operator. A hearing by the Board of Trustees was followed by a warning from the District Attorney's Office that legal action will be taken if the nuisance is allowed to reoccur. Responsibility is placed directly on the property owner.

An unprecedented mosquito annoyance persisted for several months within the Cities of Santa Ana and Tustin (70,000 population) as the result of a mass migration of *Culex* species from a 500 acre source located some three to five miles from the residential areas. The source was created by the treatment of sugar waste water by its use for raising feed on duck clubs and by its disposal on furrowed ground.

An important mosquito control problem has rapidly developed within the County by the construction of over 1000 subdivisions within the County during 1954. Many small breeding sources have been created by installation of open drainage channels in easements paralleling backyard property lines.

A potential but interesting problem is in the making for 1955 with the rapid completion of Disneyland with its miles of water ways. Assistance on mosquito control already has been requested by Disneyland Administrators, and a review of the aquatic growth and fish life planned for this artificial wonderland is under way.

MOSQUITO SOURCE REDUCTION PROGRAMS IN SOUTHERN CALIFORNIA IN 1954

ARTHUR LEE, *Entomologist*
San Diego Department of Public Health

San Diego County is 4,258 square miles in area, of which 814 in the west are under routine supervision and control. This section contains a rapidly expanding port, naval facilities, salt marshes and sloughs, communities almost continuous from the northern border of Tijuana in Baja California, dairies, truck gardens, and orchards.

For purposes of control, this area has been divided into four sections, each, roughly, of a size that can be handled by one vehicle: (1) San Diego City proper; (2) the southern to the border; (3) the north coast; and (4) the northeastern. One vehicle, that covering the north coast with its many sloughs, has power equipment; the other areas are covered with hand equipment routinely. In addition, a flat-bottomed boat with outboard motor is fitted to take the power equipment in order to penetrate the sloughs. When the water recedes so that it is no longer possible to use the boat, a small caterpillar tractor, fitted with wooden cleats to double the width of the tracts, receives the power equipment. If other sections require assistance, any of the power equipment may be shifted into that area.

Control measures can be divided into two main phases, seasonal and year around; the first further subdivided into (1) rainwater and (2) irrigation problems; the second into (1) dairy and plant wastes, (2) septic-sewage runoff, and (3) tidal.

Rainwater problems are usually readily handled by extensive distribution of *Gambusia*; but in the north coast section the rain runoff gathers in the sloughs, which, with their abundant vegetation of pickleweed and tules, are relatively inaccessible to fish and difficult to spray. As summer progresses, much of this improves; but the addition of sewage effluent to one or flooding for a hunting preserve in another, prevent complete drying and keep small foci available for rapid mosquito development and spread in the spring.

As the effect of the rains vanishes, irrigation becomes a problem. Excessive watering of lawns, with its accompanying waste, creates a need for routine spraying of sumps in the metropolitan area; although in actual practice only San Diego proper and Coronado receive this service. With the rapid growth of metropolitan San Diego, many new tracts are being incorporated within the older communities. Many of these housing developments have encroached on land previously used for truck gardening and even surround some such farm lands. This has often upset the natural drainage and created new problems. Where the water has not acquired harmful salts from leaching, a sump-pump arrangement satisfactorily utilizes the waste water, but this process has only limited use in the county.

Similarly, the dairy wastes may be utilized for permanent pasture, thereby often eliminating their nuisance as a source of mosquito breeding. Educational programs are quite effective with the dairymen, as it can be readily shown that he is not only abating a nuisance and thereby creating goodwill with his neighbors, but that he is aiding himself economically in creating good pasture and increasing his milk output by reducing the annoyance to his cows.

As a Health Department, we lack an ordinance whereby we can force a property owner to correct a condition or else we can move in and bill him for the service, as I understand can be done by the M.A.D.'s. We have only an ordinance governing the abatement of a nuisance, which is difficult to enforce. However, correction effected through persuasion often pays dividends in the long run, since there is no resentment on the part of the owner, which often arises where force has been applied, and there is frequently a carryover so that future conditions may be corrected or avoided without any effort on our part.

The correction of septic tank overflow is in the setting up of new sewage disposal systems or annexation to those already existing. When the ground is no longer able to absorb the waste of new housing, the area is sufficiently populous for other means of disposal. Unfortunately, this often means new problems as the existing systems to which they unite are frequently already overloaded.

An attempt was made to control the breeding in the aeration pond at the Loma Alta sewage plant, Oceanside, by the use of a substance not harmful to the yellow-green algae used to oxygenate the water which is added to the raw sewage to reduce its odor. A "wetting agent," Oronite D-40 was obtained through the courtesy of Braun and the area was sprayed at different concentrations up to 10 lbs. per acre, at which concentration we were using 20 lbs. At 16.5 cents a pound, the cost for the "wetting agent" alone would be $3.30 per treatment, if successful. Since the quantity of lindane required to keep the mosquitoes suppressed costs less than $2.50, it was felt that it would not be practicable to use the "wetting agent" in quantities beyond this figure. The only observed result from the application in concentrations ranging from one pound to ten pounds per acre was an instability and loss of equilibrium among the pupae almost immediately after spraying with all concentrations, but little effect on the larvae was observed up to three or four days following each treatment.

Of interest to the entomologists, may be the apparent wider distribution of *Culex tarsalis* throughout the county than in past years and its seeming change in breeding sites; in that, while it still appears to prefer fresher water than *C. stigmatosoma,* often it was found in pure culture in sewage effluent and septic runoff.

From this relatively brief survey of the source reduction program in San Diego, we in Southern California can see wherein lies a community of interest and common solutions to our problems, as well as the individual variance of emphasis necessitated by local considerations. The points we have in common are so much greater than these variances that, if there were no association such as meets here today, it would be imperative that one be organized for the free exchange of ideas and past experience. It is in this utilization of proven theories and backlog of experience that the association proves itself economically sound and worthy of the fullest support by all members of our communities.