PROCEEDINGS AND PAPERS

OF THE

Thirty-fifth Annual Conference of the

California Mosquito Control Association, Inc.

AND THE

Twenty-third Annual Meeting of the

American Mosquito Control Association

AT THE

SHERATON PALACE HOTEL
SAN FRANCISCO, CALIFORNIA
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THOMAS D. PECK

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DEDICATED TO THE MEMORY OF

OSCAR VERNON LOPP (1905-1966)

In 1959 Oscar Lopp came to California as Manager-Entomologist of the Merced County Mosquito Abatement District to cap a long and brilliant career of public service. In this final responsibility he served with exceptional distinction and great energy until suddenly, while participating in the 1966 Utah Mosquito Abatement Association meeting, his tenure on earth came to an end.

By his technical competence, his dedication to the task he had undertaken, his unwavering adherence to lofty principles, his cooperative demeanor, and his friendly though firm guidance of those under his direction, he won the respect and friendship of the policy-making board of the District and other county officials, as well as the inspired support and cooperation of the District employees. Under his leadership, the plant and program of the District were continually improved, and many technological innovations were introduced to maintain the operational program among the best in the nation.

In recognition of his contributions to progress within his profession, his contemporaries in 1966 elected him President of the California Mosquito Control Association. He also had a long record of serving the American Mosquito Control Association in a variety of ways.

Oscar began his professional life with training at the University of Louisville, receiving his B.S. degree in biology and chemistry in 1928, followed by an M.S. in entomology and forestry from the University of Minnesota in 1931.

Immediately before coming to California (1955-1959) Oscar had been entomologist for the South Cook County (Illinois) Mosquito Abatement District. His earlier assignments had included tours of duty as superintendent of the USDA Soil Conservation Service tree nursery at Havana, Illinois; Wildlife Research Worker for the Indiana State Department of Conservation; and Entomologist and Agricultural Research Worker for the Firestone Rubber Plantations Company, Liberia, West Africa, which included an important malaria control responsibility. From 1943 to 1947 he was a Captain in the Army Sanitary Corps, performing a variety of entomological tasks in malaria control, aerial spraying, etc., with service in the United States, England and France. In 1947 he served CDC as State Entomologist of Alabama, and in 1954 became entomologist for the Cumberland Field Station at Prestonburg, Kentucky.

Oscar Lopp will long be respected and appreciated as one who served well his fellow man and his profession. It is in this most appropriate recognition that this Joint Conference is dedicated to his memory.

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TABLE OF CONTENTS

CALIFORNIA MOSQUITO CONTROL ASSOCIATION

AMERICAN MOSQUITO CONTROL ASSOCIATION

FIRST SESSION

MONDAY, FEBRUARY 6, 9:00 A.M.

STEPHEN M. SILVEIRA, *Presiding*

CALL TO ORDER

STEPHEN M. SILVEIRA, *Acting President*
CMCA, *presiding*

Good moning, everyone! It is indeed a pleasure and privilege to call this 23rd Annual Meeting of the AMCA and the 35th Annual Conference of the CMCA to order. We in California welcome each and every delegate, visitor, members of their families and their friends to San Francisco.

It is our earnest hope that you will enjoy the many fine speakers on our program and that the exchange of ideas and experiences will benefit each of us and the organization we represent.

Oscar V. Lopp, 1966 President of the CMCA and Manager-Entomologist of the Merced County MAD, passed away suddenly due to a heart attack on September 13, 1966. His sudden death was a great shock to many of us. All of us who knew Oscar and cherished his friendship, miss his presence at this conference.

We wish to dedicate this meeting to the memory of Oscar V. Lopp.

I declare this joint session of the American Mosquito Control Association and the California Mosquito Control Association to be in session.

MOSQUITO CONTROL AND THE CALIFORNIA WATER PLAN

CARLEY V. PORTER
Assemblyman, 38th District
California State Legislature

Mr. Graham, distinguished guests, members of the American and California Mosquito Control Associations. It is a pleasure to be with you this morning to discuss the relationship between mosquito control and the California Water Plan.

This is a topic which I think was quite properly assigned to me. I am Chairman of the Assembly Committee on Water, and wherever you have mosquitoes you first have to have water. I think you probably wanted to find the man responsible for the water and find out what we are doing in the California Water Plan about this matter of mosquito nuisance and the threat to public health.

Are we doing something about it? The answer is, "Yes, very definitely."

I should first explain briefly what is meant by the "California Water Plan". Basic studies of California's water resources began in the early 1920's with legislative appropriations to our former Division of Water Resources.

Our planning efforts were accelerated during the late '40's and in 1947 the legislature authorized the specific detailed studies which culminated 10 years later in the issuance of Bulletin No. 3, *The California Water Plan.*

On page vi. this document described itself as, ". . . a Master Plan to coordinate and guide the planning and construction of all agencies of works required for the control, protection, conservation and distribution of California's water resources for the benefit of all areas of the state and for all beneficial purposes."

The Water Plan included evaluations of existing supplies and requirements, estimates of surplus waters and a broad outline suggesting the manner in which the state's waters could be best developed. The Plan encompasses several hundred individual completed and proposed water projects which have been or will be constructed by federal, state and local agencies. The legislature enacted the Plan into law in 1959 and in its present form the California Water Plan represents a "total approach" to water resources planning in California. It is a flexible plan, however, and we are constantly updating it and modifying it as the changing pattern of growth and development of our state unfolds.

In approaching my subject today—the relationship between mosquito control and water development under the California Water Plan—I am going to limit myself to a discussion of the state's Feather River Project, which is the biggest and first part of the California Water Plan. This is the California water development with which I am most faciliar, having coauthored the legislation in 1959 calling for the $1.75 billion bond issue (approved by the voters in 1960) under which the Feather River Project is being financed.

Incidentally, the Project is now at midway point in construction. At maximum capacity in 1990, it will deliver more than 4.2 million acre feet of surplus Northern California waters to Central and Southern California. The Feather River Project is just one project of the hundreds that comprise the California Water Plan. However, the Project, with a great variety of different types of reservoirs, dams and transportation facilities, exemplifies the full range of mosquito control problems which result from water development under the California Water Plan.

As most of you are probably aware, California is now the most populous state in the Union. In the last decade we have gained almost 6 million people — a 45% increase. During the same period, about 1 million acres of irrigated land have been brought into production, bringing the state's total to over 8.5 million acres. One of the more important aspects of this growth, especially as it affects planning for water development, has been the regional shift in agricultural expansion.

The great growth of metropolitan areas, principally the Los Angeles and San Francisco Bay areas, has forced thousands of acres out of agricultural production. To a great extent, this loss has been the Central Valley's gain, with relocation particularly in the San Joaquin and Tulare Lake Basins. The latter area alone has accounted for about half of the increase in irrigated acreage during the past ten years.

Thus, it can be seen that the growth of our urban areas, while increasing urban water requirements, has also contributed to the growth of agricultural water requirements in California.

The correlation between the California Water Plan, that is, the states many water development projects, and mosquito production potential is composed of a number of overlapping cause and effect relationships. Broadly speaking, they can be broken down into the *conservation and transportation, local distribution and use*, and *disposal* phases of water resources development.

Conservation and Transportation

The Feather River Project is an excellent example of a major effort in conservation and transportation of water resources. The Project is the largest single development and transportation system for water in the world. No state has ever attempted a project of its magnitude.

Any water project, whether state, federal or local, has the potential, either directly or indirectly, for mosquito production, and the Feather River Project is no exception.

As a result of precautionary measures taken, our Department of Water Resources is confident that the various facilities of the Project, when in full operation, will provide little opportunity for production of mosquitoes. For example, the reservoirs normally will be operated so that the water surface will fluctuate almost daily. The lowering of the water surface is beneficial to mosquito control as the eggs are left to dry and, thus, are unable to survive. The lowering of the water surface also reduces peripheral and marginal vegetation, making the reservoir edge less suitable for mosquito breeding and the mosquitoes themselves more susceptible to predators.

The miles of canals in the transportation features of the Project will also be unfavorable areas for mosquito breeding, as they will have steep side slopes, concrete linings and fast water velocities of up to 4 feet per second.

The Department has been actively working to assure success in the battle against mosquitoes. For example, during construction the borrow areas (which are the natural sources of rock for dam construction) have to be drained. Also natural drainage areas blocked by construction and by the canals themselves have to be provided with alternative drainage facilities.

In the future, the state plans recreation developments and wildlife enhancement areas, particularly along the aqueduct in the Central Valley. These must be maintained in a manner that will not create mosquito problems.

In 1959, the legislature recognized the need for coordination between the State Department of Public Health and various federal, state, and local water developments and created the position of Vector Control Specialist in the Department with the specific task of reviewing proposed water projects in an effort to minimize mosquito production.

The California Health and Safety Code, in Sections 205 and 206 provides that agencies operating water projects may be required to provide adequate safeguards for facilities within their responsibilities. These agencies include the State Department of Water Resources, other state departments and local water dis- districts which, in many cases, contract with local mosquito abatement districts to provide for mosquito control. In some cases they provide this service themselves. With regard to the State Project, there are some areas along the aqueduct where no mosquito abatement districts now exist. In this case, it will be necessary either for local districts to contract to abate mosquitoes outside their boundaries or it may be necessary to form new districts.

Local Distribution and Use

Probably the most significant impact of water projects, including the Feather River Project, on mosquito production, is in the area of local distribution and use.

Millions of dollars will be spent on distribution facilities in the local service areas of the 31 public agencies which have contracted with the state for Project water. For example, the agricultural areas of the Central Valley will receive more than 1.3 million acre feet of water from the Feather River Project and local distribution facilities needed are now estimated to cost more than $200 million. There will be miles and miles of irrigation ditches, canals and other local facilities, each of which will require mosquito control protection.

Water, after coming through the state's transportation facilities and the distribution facilities of local agencies will then be further distributed on farm lands through intricate irrigation facilities.

Poor irrigation practices probably make the most significant contribution to mosquito production, particularly the practice of leaving water standing for a week or more to leach or irrigate fields. This provides ideal breeding conditions for certain species of mosquitoes. It is necessary for the topography in new lands to be developed in such a manner as to provide proper drainage to prevent mosquito production. Along this line both the state and federal governments will provide major drainage facilities in the San Joaquin Valley.

Good irrigation practices, however, are consistent with good mosquito control, and farming operations with high water use efficiency generally do not have mosquito problems.

With Agriculture Director Coke here I should mention a fact which the public often overlooks. In spite of the fact that there has been tremendous growth in our state's population, primarily in our urban complexes, today 88% of the total water used in California each year is for *agricultural* purposes. Thus, domestic and industrial water accounts for only 12% of our water use.

Irrigation, of course, provides but one of the many opportunities for mosquitoes to propagate. Spreading basins and sewage lagoons also have created significant mosquito problems and require the ingenuity of mosquito control district people to assure public health protection.

Disposal of Waters After Use

Finally, an important aspect of the California Water Plan and water development projects in relation to mosquito production is in the disposal of waters after use. Water is too precious a commodity to waste. Maximum reuse must be made of our existing water supplies. Consistent with this need, the Assembly Water Committee has just released a report recommending an all-out state and local effort to develop waste water reclamation facilities. The Committee is proposing legislation to declare the state's primary interest in the development of waste water reclamation facilities. Financial assistance for initial local studies and for loans for project construction is provided by the proposed legislation. This should help local agencies in integrating water reclamation projects with existing water development programs, and sewage and waste disposal programs. Waste water reclamation is a frontier area in water resources management and should have a favorable effect on mosquito control.

Water management must include a complete utilization of our total water resources, including waste water reclamation, and the planning and cooperation of both developers and users to assure the control of water-associated problems such as mosquitoes.

In conclusion, water developers, including the state, today have a responsibility for mosquito control in their reservoirs and canals, both during construction and during operation. This can be accomplished by cooperation with qualified mosquito control persons in the planning, development and operation of the Project.

Mosquito abatement districts have provided outstanding service in this regard to our state for many years. I am pleased to say that the area in Los Angeles County from which I come has several of the state's finest mosquito abatement districts. I have enjoyed working with them on legislation and local problems through the years.

In addition, the local water user must be constantly aware of the mosquito problems resulting from the use of water. Good farming practice should be encouraged because it brings with it good mosquito control.

Finally, developers and users must recognize the problems of disposal and the use of new procedures such as waste water reclamation. Full coordination between state and local agencies responsible for vector control is also necessary for success in our unending attack on this problem.

This is just a brief outline of some of the problems that major water development projects and their associated facilities cause in the area of mosquito control. I know that during the coming days of your convention the real experts in these fields will be filling you in on more technical matters. But I can assure you that the State of California, with regard to its massive water project, will make every effort to assure the best possible mosquito control measures along its miles of waterways and at its reservoirs and other facilities.

MOSQUITO CONTROL IS COMPATIBLE WITH AND BENEFICIAL TO AGRICULTURE

Allen M. Grant

California Farm Bureau Federation, Berkeley, Calif.

It is a pleasure for me to speak to you on behalf of and in the interest of agriculture and its relationship to mosquito control. Having been in farming for 38 years, the inclination is to reminisce. The mosquito situation then was considerably different from what it is today.

We oiginally farmed with horses and mules. I can well remember – the horses and mules would not leave the corral to go out to the pasture, because the mosquitoes were so bad. Not only that, but we were in the dairy business, as we still are today, and the cows would not leave the corral. In those days we pastured cows between milking, not the way we do now, by bringing the pasture to the cows. The cows simply would not pasture at night because there were so many mosquitoes in the pasture.

We corrected some mosquito breeding areas on our own – we straightened the river when we bought the property and we built levees to keep the water from flooding over. Prior to that, the mosquito abatement district operators had to spray many pools throughout the underbrush, the blackberries and the willows. It was almost impossible to control the mosquitoes in these breeding areas. Also, people would use these areas to dump mayonnaise bottles, tin cans and such receptacles which provided additional breeding sources for mosquitoes.

As we developed our land – graded it and brought it under irrigation from the original native pasture, we began to find some things happneing that we couldn't understand. For example, we found that, where we had irrigation ditches, water would stand long after irrigation was finished. Also, water stood in pools in various spots for a while. Cattle are like some people – they don't want to do any more than they have to. They wouldn't go up to the water trough when there was water close by.

One year we had 24 heifers abort calves. We moved them out of this area, put them in a dry corral, fed them hay, had them drink only from a trough, and we stopped the problem. The next year we had 19 heifers abort calves in the same field. We moved them out and stopped the problem again.

We decided that perhaps the mosquito abatement people were right; that we shouldn't have the water standing on the land. We put in underground pipe lines, divided the field into various pastures, and kept the cattle out while the field was being irrigated, and we eliminated the problem completely. So the changes we made to help our farming problems were quite compatible with the recommendations of the mosquito abatement district.

We leased some land to a cotton grower. Water at that time was pretty cheap, about $5 an acre for a full year's irrigation. This cotton grower was not very particular with his water, so in order to cut down on his expenses he cut down on his labor bill – and let the water flow. He had a lot of water standing in the low end of his field. I don't have to tell any of you how difficult it is to kill mosquitoes under cotton plants, which may be as tall as 6 feet in some of our river bottom land in the San Joaquin Valley.

Now the increasing cost of water is causing people to be more careful with it, so they won't have it standing in the fields so much. They use it more efficiently. About 25 years ago I asked the Agricultural Extension Service in my home county of Tulare to bring us information on better use of water. The then Director of Extension told me he could show me two cotton farmers, one of whom irrigated his cotton 6 times in 1 year and another farmer across the fence who got the same kind of production with 3 irrigations in a year. So we have learned that the encouragement of the mosquito abatement program to make better use of water and to avoid having standing water is fully compatible with the farmer's interests. I personally have benefited from the cooperative program of the mosquito abatement district in which I live and farm. I leased some other land, on what is called Lewis clay loam soil. This is considered to be the poorest type of soil in our county. It holds water about like a mayonnaise jar, and you cannot punch a hole in it with an axle from an old auto. We have given up that lease now, but for the several years when we had it we raised up to 600 head of Holstein heifers on it. With our dairy operations we butcher every so many weeks and divide the meat among the employees as one of the fringe benefits of working on our dairy. We always throw the livers away, because we had liver fluke so bad that we couldn't use the liver on any animal that was raised on that property. Of course these flukes are not conducive to good growth of the heifers. Also, I believe you can understand that, since the fluke must have standing water for part of its life cycle, this property was conducive to the production of lots of mosquitoes. We didn't have that problem on our own property, because we had the property divided into separate pastures and we did not put the heifers on it until the ground was dry. This again was a compatible relationship between mosquito abatement, the Agricultural Extension Service and the farmer, all learning how to use the land and the water to better advantage.

Also, we learned that where we had too much water on the land for too long a time we were troubled with rhinotracheitis, leptospirosis, foothill abortion, and in addition we had the danger all the time of encephalitis. Back in 1940, when the mosquito abatement program was not well developed as it is today, we had a son who had encephalitis. If I were not interested in mosquito control from my point of view as an agriculturist, I would still be very interested as a citizen of the community because of our son.

What about the use of chemicals? I believe agriculture and mosquito abatement work side by side in the safe use of chemicals for the benefit of agriculture and the public health. Certainly we are operating compatibly here.

Assemblyman Porter noted the coming increase in population and recreation. We in agriculture will have to relate ourselves to these changes. If we cut down on the incidence of mosquitoes, flies, dust, odor, noise and other things which bother great numbers of people when we have agriculture near this burgeoning population, then we can help minimize the pressure of the urban people on the agricultural industry.

In closing, I want to note that mosquitoes have a strong effect on farm employees. I mentioned in the beginning the difficult time we had in the late 20's with mosquitoes. It was almost impossible to keep a man on a mowing machine seat, because when he sat on that seat it drew his trousers tight, and the back of his shirt was tight. Mosquitoes readily punctured the tight clothing and the man would quit. The very presence of mosquitoes makes a difference in agricultural production, both because of their effect on the employees and on the animals. With our coming need for food for the hungry of the world, every single thing we can do to help increase the production of agricultural products will be well worth while. So the increased agricultural production which mosquito control helps to provide is certainly justification for the excellent cooperation we now have between agriculture and mosquito abatement.

WORLD-WIDE MOSQUITO CONTROL, A GROWING PUBLIC HEALTH NEED

RICHARD F. PETERS
California State Department of Public Health
Bureau of Vector Control, Berkeley

Mosquitoes alone, without even considering their infamous role as vectors of malaria, yellow fever, encephalitis, filariasis, dengue, hemorrhagic fever, and various other diseases of man, are clearly eligible to be included among the significant public health problems of the world. Perhaps the endless distress caused the world's people from so-called "pest" mosquitoes even approaches in importance the acknowledged disease aspect. Certainly on the basis of combined vector and pest impact, mosquito control deserves vastly greater acceleration almost everywhere in the world, including, alas, the so-called "developed countries".

The World Health Organization in its constitution regards public health to be "a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity". This would indicate that mosquito control is part of the public health needs of the world. The U.S. Public Health Service Surgeon General over a decade ago clearly enunciated pest mosquito control to be eligible for public health attention; yet, despite these two profound pronouncements, the fact is conspicuously evident that the world-wide needs of mosquito control have not even begun to be adequately recognized, let alone met. Further, forces are operating throughout the world which portend greater mosquito problems as each year passes, and cause increasingly complex social and environmental changes.

The latitude afforded me in this title is considerable — perhaps not so in this space age — but given the world and world-wide mosquito control as the theme of this meeting, I am sure you realize I am likely to stop at very little.

During the years of my public health career, and it is a little disturbing to recognize that it is now approaching the close of the third decade, I have traveled to diverse parts of the world on a number of occasions, in both military and civilian capacities related to mosquito Control. Everywhere the evidence of mosquito impact upon man has been conspicuous. The average person in the United States, particularly within the jurisdictions of those of you representing local mosquito control programs, would be shocked to know, although he accepts mosquito control as the expected thing, that most of the people in the world (of which there are now about three billion, with the uptake considerable) are subject to mosquitoes on a 24-hour basis nearly every day of the year. You might remind your people at home that they are indeed among the fortunate. The majority, furthermore, live in open shelters—so wide open as to be incapable of excluding mosquitoes. Carrying the predicament of the great masses of this world even further, the average person doesn't even have a bed to sleep on, in the sense that we are accustomed to our furniture for slumber. So you can realize that the human population is very generally exposed to mosquitoes around the world.

Another unique aspect of underdeveloped parts of the world, is that the water supplies are collected off roofs with each rain in convenient receptacles of every size and shape imaginable that will hold water. These represent domestic water need containers. In event of fire they become the fire-fighting resources. Generally speaking, this great variety of water-filled containers encircling the individual premises is writhing with mosquito larvae. I don't know whether these people assume larvae to be an essential characteristic of water, or in any way associate them with mosquitoes. In fact, I don't know if they screen the larvae out with their teeth or drink them for their supplemental diet, but it is astonishing to realize this proximity of mosquito sources being completely ignored.

Frankly, I have often been distressed and perplexed by the unilateral emphasis to date upon mosquito vector control as contrasted with mosquito control in its most comprehensive sense. This dilemma first appeared to me in the WPA-operated, extra military program early in World War II, and persisted throughout the successor Mosquito Control in War Areas program conducted by the U.S. Public Health Service. In these instances, we were required to confine the control target to *Anopheles* species occurring within one mile of military bases or other areas of strategic military need.

That this condition was ludicrous for California had been suggested by Freeborn, who, during the 1920's and 1930's, on the basis of prima facie evidence, had concluded that his namesake, *A. freeborni* Aitken was capable of flights of at least 20 miles. Yet, the policy was firm. Even more important, the accumulating evidence by Doctors Meyer, Hammon and Reeves, incriminating culicine mosquitoes with the transmission of encephalitis, wasn't even recognized as an area of control eligibility for this program.

Beyond the malaria and encephalitis consideration, even during World War II, as Assemblyman Carley Porter in his presentation implied, a considerable irrigation development was under way and a sizable mosquito problem had already manifested in California. 1937 was the first record of *Aedes nigromaculis*, our most troublesome pest mosquito, presumed to have been imported, which rapidly covered the floor of the great Central Valley. This mosquito, which is capable of flights of considerable distance was not eligible for control. The personnel of the military bases and other strategic areas of the state couldn't be protected against this mosquito, which particularly at that time, with a very low level of civilian mosquito control, actually interfered with and disrupted everything in the way of military or other essential operations. Mind you, the ground rules applied only to control of vectors of malaria within a one-mile radius!

These several illustrations could be reinforced almost anywhere else in the United States where equally aggressive mosquito species from the seashore marshes to the inland swamps, to the river bottom lands, to the snow-capped mountains in which these "pest" mosquitoes are responsible for "vectoring", if you will accept this connotation, a massive discomfort to the public. In many instances, notably in the states of New Jersey, Florida, Virginia, New York, the New England states, Louisiana, Texas, Utah, Minnesota, the Pacific Northwest and, of course, California, the public has made it evident that they don't intend to be sacrificial offerings to public health pest mosquitoes, and I am sure they never intend to look back.

Thus, I have long been convinced that the sharp distinction between vector and pest—disease and discomfort—is a remote, ephemeral one which can often best be ignored in a public health program which operates in the public interest.

In California we define vector control as "the scientific suppression of insects and other animals which adversely affect the public health and well-being, accomplished through a program of environmental conservation measures, aided by appropriate chemical and biological control technology".

In the interest of administrative practicality, we have found it advantageous to expand the word "vector" to include the great variety of "homininoxious" animals which interfere with the safe and comfortable use of the residential, occupational and recreational areas. This liberty in broadening the definition of "vector" has been taken purposefully and the public reaction has been without objection to such a semantic abridgement. Really, the underlying importance of this action is that of facilitating maximum program effectiveness and overall health benefits to the public, which is neither equipped nor willing to distinguish between being victim of a vector or distressed by a pest.

The next great example of unilateral control emphasis upon vector mosquitoes came with the concept of malaria eradication—a most unique and effective program, but thus far incredibly limited, as it relates to mosquito control. I am sure it is the popular opinion that malaria eradication is primarily a mosquito control program. Actually it is only in part an adult *Anopheles* control program, with control predicated upon anopheline female mosquitoes coming indoors and resting on a surface previously treated with a residual insecticide that will presumably persist for a protracted period of time. The primary emphasis is suppression of the *Plasmodium* of malaria by way of putting into perspective the relative importance of the two phases. Eradication has been carried out with considerable success on the epidemiological side, but I am sure that everyone in this room realizes that mosquito adaptations expressed as resistance have shaken the foundations of this concept in many of the malarious areas of the world. Accordingly, the program is overdue for a new outlook, and I am pleased to recognize that new looks are under way. Speaking as a representative of the field of biology, I admit unhappiness and displeasure at the failure of the founders of the malaria eradication concept to have utilized this profession at the outset in order to determine and utilize ecological and ethological knowledge of vector species as a basis for determining what, where, when and how control technology should be used. Not being affiliated with an eradication effort, I can afford to be pretty broad in my challenge. Of course, I may never again be invited to go on a program assessment anywhere, but I sincerely believe this to be a severe and serious omission from which the program has not yet recovered.

So perhaps, the world malaria eradication needs, which we will shortly hear about from Don Schliessman, might well consider the appropriate use of biologists in carrying forward this vital and increasingly demanding world need, hopefully on a much broader mosquito control foundation.

Now having taken the liberty of working over, to a very moderate degree, the malaria eradication programs of the world, I would be derelict if I didn't next shift to *Aedes aegypti* eradication. Again, this is a unilateral approach to control of a single species of mosquito in a setting of many pestiferous mosquitoes. I am sure the problems are evident without my enumerating them, but in any case, my quarrel is not with the need for or the desirability of this program although, of course, California is providing about 10% of the budget and not getting one red cent in return, despite mounting the biggest mosquito control program in the nation. But this is one of the fortunes of federal functions. The thing I believe to be most important, is that every congressman who supported the funds for this program sincerely believes he has provided for all the mosquito control needs of the 50 states and 1 territory. This is the way the mind of a congressman operates. An interesting aspect of this matter is the Patton-Boggs Bill before the Congress which seeks to obtain additional funds for mosquito control in the context that I would advocate. I am sure these authors will now find it tough sledding, even if the bill were unequivocally endorsed by this Association. Those of you who attended the AMCA Board meeting yesterday know to what I refer.

Shifting back to the world scene, and the growing public health importance of all mosquitoes which affect man, the following developments and trends are underway which demand greater mosquito control effort. To begin with, the world is experiencing a population explosion. Translated, this only means more people to cause more mosquitoes—mosquitoes that will immediately begin to search for victims of their bloody intentions. The next obvious effect of more people is the trend towards urbanization. People are gradually shifting from the remote parts of the world and concentrating in megalopolises. This imposes the need for comprehensive and organized handling of liquid wastes. Incomplete handling of liquid wastes is an invitation to that cosmopolitan mosquito you are going to hear more about this afternoon from Dr. Kessel — *Culex pipiens* (*fatigans*), which thrives wherever liquid wastes find their way. This problem as it relates to filariasis, and as world-wide pests in every nocturnal hour, is a staggering one yet to be effectively dealt with.

After Mr. Allen Grant's presentation earlier this morning, and from the inferences of Assemblyman Porter, I am sure I hardly need dwell on the absolute necessity of incorporating mosquito prevention within all the major agricultural developments occurring around the world. The philosophy we employ in California is the frequently quoted one of public health—"an ounce of prevention is worth a pound of cure". California itself has experienced within a short span of 20 years an increase in program cost from $500,000 in 1946 to nearly $8 million in 1966, mostly occurring in the agricultural areas of the state, although certainly, also to a lesser extent, in the community areas as represented by the very locality in which Assemblyman Porter lives.

In the course of one of my world travels I had the opportunity to see the plans within the USSR for agricultural irrigation expansion. They have scheduled an irrigation development twice as great as that which we have programmed in the United States, and our plan calls for about a quadrupling of our present irrigation resources. Incidentally, California presently has about one-quarter of all the irrigated land in the United States, and even after the development of all irrigable areas in this country, we will still have about one-fourth of all the irrigable land provided water from mountain water sources.

Then, of course, we cannot turn our heads and ignore the increasing problem of mosquito insecticide resistance, which in itself demands a broadening look at the preventive and the biological alternatives to the use of chemicals. We do not expect to completely substitue for chemicals, but certainly complementary measures are needed, more so than has been the case in the past.

I believe that many of the needs of underdeveloped areas of the world can be met by simple education, resulting in improved patterns of living through organizing people in their various jurisdictions to understand where mosquitoes come from and to take steps to help themselves. I would certainly hope that the world of the future will give more attention to the structures in which people live, designing them in such a way as to permit exclusion of mosquitoes. This may appear way out, but I wonder if closed units with air conditioning are as far away as it may sound at this moment. Certainly screening of soundly-built structures is a minimum need within attainment. We have taken screening for granted in this country, yet one does not find screening very generally throughout the world.

Finally, the challenge to the AMCA is one of shaping and helping to accomplish the needs of the future. We must expand our perspective. We now define ourselves as American, at least in the Pan-American sense of the Western Hemisphere. We have technical counterparts around the world, many of whom speak other languages, and who have just as much technical competence and capability of communication as we do among ourselves here today. I do believe that the American Association has the potential to become a World Association. Ours is a unique Association, being dedicated on a voluntary basis to public service, the mission being to communicate information for the protection and the preservation of the health and comfort of the people of the world against mosquitoes and other vectors of disease and discomfort. It is entirely within the scope of realm of this Association to achieve this broad objective as a long-range target. So, I would urge the Association at large to contemplate this as a horizon for tomorrow, because the problems caused by mosquitoes and related animals resulting in human discomfort and disease are going to get worse before they get better, unless they receive appropriate preventive program.

In closing, I realize the huge problems that attend the financing of world-wide mosquito control. There undoubtedly will have to be greater governmental acceptance of responsibility. Certainly the WHO and all other interested world service organizations, could expand their scopes toward this objective and thereby aid and facilitate bringing into being the prospect of world-wide mosquito control. It won't come easily or soon, but my attitude is: never undertaken; never acomplished.

TECHNICAL SESSION

CONCURRENT

MONDAY, FEBRUARY 6, 1:30 P.M.

HARRY D. PRATT, *Presiding*

DIETHYLCARBAMAZINE IN FILARIASIS CONTROL

JOHN F. KESSEL
School of Public Health
University of California, Los Angeles, Calif.

The two excellent summaries by Hawking (1955 and 1962), concerning the chemotherapy of filariasis, point out that none of the drugs extensively used in the earlier treatment or control of animal parasitic diseases other than filariasis has proved to be the answer for filariasis.

With the possible exception of the antimonial and arsenical compounds described at the last WHO Expert Committee Meeting on Filariasis (1962), no new filaricides are being extensively studied. Lartigue & Ovazza (1966) are using Trimelarsan (Mel W, 9955 RP) in the treatment of onchocerciasis with reported safety and success. However, preliminary studies concerning its use in filariasis still indicate the necessity for caution, and further reports are being awaited with interest.

Hawking (1962, Table 1) tabulates 20 reports from different parts of the world in which diethylcarbamazine was used in control programs. The microfilaria rates are shown before and after treatment, along with the percentage reduction in microfilaria density. It would appear from his review that diethylcarbamazine is the one drug shown to be safe and at the same time highly effective in lowering filarial infection rates.

There are, however, great variations in the reported reductions of microfilaria infections following use of diethylcarbamazine as listed in Hawking's report. These fall into two groups: first, "total population groups," as in islands, villages or districts in which mass treatment has been administered, the positives in the post-treatment follow-up group ranged from 1.3 per cent to 16 per cent. Second, "groups of carriers," each showing 100 per cent to be positive for microfilariae prior to taking diethylcarbamazine; in this group, the post-treatment blood surveys showed from 8 per cent to 90 per cent still to be positive. These marked differences in post-treatment rates undoubtedly stem from variables in each of the groups, such as: (a) different microfilaria rates and densities before treatment, (b) different regimens of diethylcarbamazine administered, and (c) different lengths of time between administration of diethylcarbamazine and follow-up surveys after close of treatment.

Although the data in Hawking's Table 1 all show trends toward lower microfilaria rates and densities following diethylcarbamazine, exact quantitative relationships between the results of the two procedures of reporting are not defined.

As the trend in future filariasis work in all probability will be toward eradication rather than control only, a more precise re-evaluation of data relating to the effectiveness of diethylcarbamazine is desirable. Extensive long-term data have been collected in Tahiti and American Samoa. As the writer has been closely associated with both of these activities, it is hoped that an analytical summary of certain key experiments may help to understand the value of diethylcarbamazine in filariasis control.

When diethylcarbamazine was first used in Tahiti by Beye *et al.* (1952), no long-term data following its effectiveness were known. The recommended dosage at that time was 2 mg per kg of body weight (t.i.d.) which proved to be an impractical dosage for mass treatment control programs.

Table 1. Raw data regarding groups A and B in Tahiti and American Samoa.

	No. examined	No. positive	% +	Av. Mf count/ person
Tahiti				
Before A	572*	172	30.0	30.0
B	60	60	100.0	56.0
After A	572	19	3.3	1.3
B	60	8	13.0	0.15
Amer. Samoa				
Before A	833	156	19.0	15.0
B	145	145	100.0	61.0
After A	675	54	8.0	0.4
B	145	38	26.0	1.8

*Incomplete

PROCEDURES

Regimens employed: Following early experiments on dosage and spacing in regimens of diethylcarbamazine for control of filariasis in Tahiti, as reported by Kessel *et al.* (1953), a minimum dose was selected of 6 mg per kg of body weight, to be given one day each month for 12 months, thus totaling 72 mg per kg. Subsequent annual follow-up blood surveys were performed, consisting of two 20 mm^3 thick blood films and expressed as the average of both. All recurrent and new positives were to be retreated following each annual blood survey. This system was to be repeated, hopefully until all people were negative.

An exception to this program was Tautira, a remote district in the northeast part of the island, in that many of the known positives in the population were given the standard dosage for an average of 26 months instead of 12, thus receiving approximately 156 mg per kg of body weight. There were 60 such people who were given follow-up blood surveys at regular intervals, for three years, without intervening retreatment.

When the filariasis control program was established in American Samoa in 1962, the standard of 12 doses of diethylcarbamazine, as originally recommended in Tahiti, was employed. However, instead of administering 6 mg per kg one day each month for the year, each person received first a daily dose once a day for six days. One group then rested for six months and received another six daily doses during the seventh month. Members of the alternate group received their second six doses at monthly intervals of one daily dose each month beginning the second month after treatment began. During the first year, the alternate group showed the greatest reductions, but by the third year follow-up results in both groups had become approximately the same.

Evaluation of results: Two ways of recording follow-up results are shown in Figures 1 and 2. The first, A, represents a population in a village or district as a whole, and furnishes an epidemiologic base line for clinical and blood surveys, and for comparison with the rates of infective stage larvae in mosquito surveys. The second, B, represents the carriers, or microfilaria positives, all of whom received the same standard regimen of treatment, and who also received identical follow-up surveys at regular intervals after the termination of treatment. They illustrate a selected group by which to evaluate the optimum chemotherapeutic results obtainable by the regimen employed.

Table 1 gives the number of people examined, the number positive in each area for groups A and B, and the microfilaria rates and average number of microfilariae per 20 mm³ of blood in each.

Table 2 represents an analysis of the 145 people in American Samoa known to be positive for microfilariae before the described treatment with diethylcarbamazine and for three consecutive follow-up surveys during the first, second and third year, the first being six months following the close of treatment.

Results

The following figures and discussion refer to data collected both before diethylcarbamazine and from the three blood surveys during the first, second and third years following the close of treatment.

In Figure 1, under A, it is observed that in Tahiti the microfilaria rate dropped from 30 per cent before treatment to 0.7 per cent one year after the close of treatment, but by the end of the third year had risen to 3.3 per cent. In Figure 2, A, the village group in American Samoa showed a decrease from 19 per cent before treatment to 3 per cent during the first year, and rose to 8 per cent during the third year. In both Tahiti and American Samoa, the difference between pre-treatment rate and the rate during the third year following close of treatment was found to be significant at a single test level of $P<0.0001$.

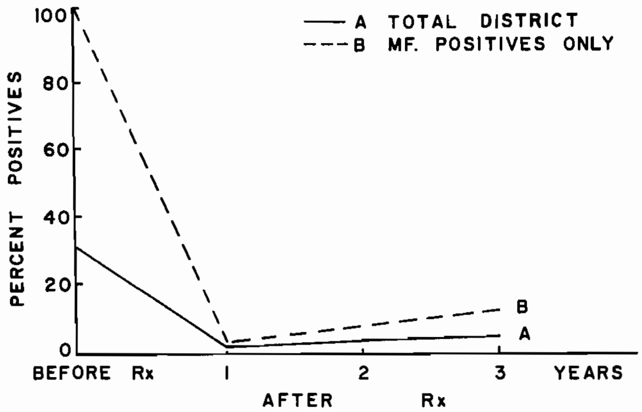

Figure 1—Microfilaria rates in Tahiti before and after diethylcarbamazine.

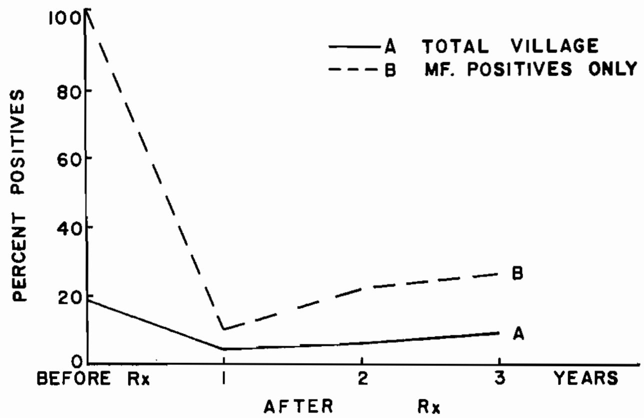

Figure 2—Microfilaria rates in American Samoa before and after diethylcarbamazine.

The microfilaria rates and average counts before diethylcarbamazine in Tahiti were higher than in American Samoa, but lower during the third year follow-up than in Samoa. This could have been influenced by the facts that more doses of diethylcarbamazine were administered in Tahiti than in American Samoa, and that the spacing was different, i.e., once a month for 12 months.

Figures 3 and 4 are composites and depict the microfilaria rates and average microfilaria counts in rural districts of Tahiti and in rural villages of American Samoa, before and after treatment, using surveys by Murray (1948), Ciferri *et al.* (1966) and Laigret *et al.* (1966).

Figure 3 shows: (1) Without mass treatment with diethylcarbamazine, as a control measure, there was little change in microfilaria rates during periods of five to ten or more years. (2) Upon mass treatment with diethylcarbamazine, there were sharp decreases in microfilaria rates during a regimen of treatment, ranging from one per cent to three per cent, by the regimens employed in Tahiti and American Samoa. (3) Without

Table 2. Detailed analysis of blood surveys of 145 posi tive people before and three years following diethylcarbamazine.

Levels of Mf counts per 20 mm³	Microfilaria counts at each level	Before treatment			Following treatment								
					1st year			2nd year			3rd year		
		No. +	% +	Total Mf	No. +	% +	Total Mf	No. +	% +	Total Mf	No. +	% +	Total Mf
1-10	1:15; 2:6; 3:4; 4:5; 5:9; 6:3; 7:2; 8:3; 9:3; 10:1	51	100	197	0	0	0	1	2	2	6	12	9
11-50	11-20:17; 21-30:11; 31-40:6; 41-50:9	43	100	1 170	8	19	16	11	26	47	13	30	29
51+	51-60:8; 61-70:4; 71-80:6; 81-90:3; 91-100:2; 101-200:18; 201-300:6;301-400:3; 400+:1	51	100	7 424	7	14	19	19	37	86	19	37	235
Totals		145	100	8 791	15	10	35	31	21	135	38	26	273

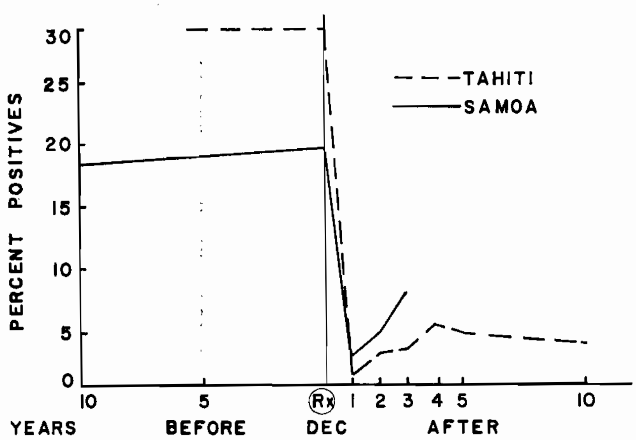

Figure 3—Microfilaria rates in districts of Tahiti and villages of American Samoa.

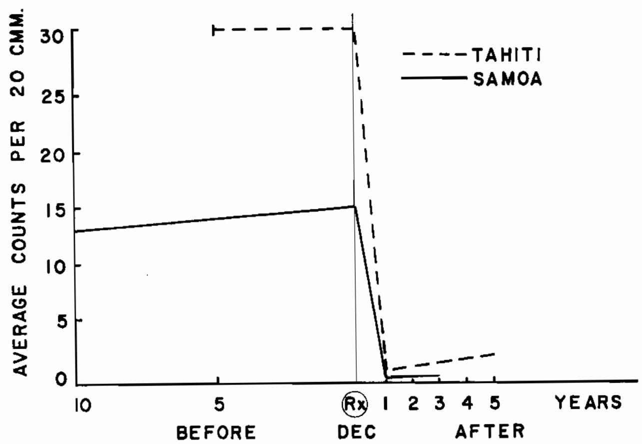

Figure 4—Microfilaria density in districts of Tahiti and villages of Samoa.

additional treatment, by the third year the rates had risen to 3.3 per cent in Tahiti and eight per cent in American Samoa. (4) In Tahiti, where the rule has been to re-treat recurrent positives along with new positives, it is seen that 10 years after treatment the microfilaria rate in rural districts is about five per cent.

In Figure 4, which shows mean microfilaria counts per 20 mm³ of blood in the same areas, corresponding impressive drops are observed. Of special interest are the low average microfilaria counts following treatment —all below two in Tahiti and below 0.4 in American Samoa.

Figure 5 illustrates the percentage of *Aedes polynesiensis* found to harbor larvae of *Wuchereria bancrofti* before and after treatment in rural areas of Tahiti and American Samoa.

In Tahiti, Vairao, a representative rural district, was selected in 1951 early in the filariasis control program as an observation or control district and was held for a number of years without diethylcarbamazine, part I, i.e., kilometers 2-8, until July, 1954; and part II, i.e., kilometers 9-14, until April, 1956. Rosen (1955) used this district as one of the three areas in which he conducted surveys, when 2390 mosquitoes were dissected, 9.7 per cent yielding all stage and 1.8 per cent infective stage larvae. Also, many of the baseline studies for the intensive mosquito surveys which Bonnet *et al.* (1956) developed were made in this untreated district.

These intensive mosquito surveys were made, usually every three months, each year from June, 1953, to April, 1954, in part I and from June, 1953, to January, 1956, in part II. Thirteen of these surveys made before mass administration of diethylcarbamazine are summarized with the following results:

	Number positive for		Percentage positive	
Mosquitoes dissected	All stage larvae	Infect. stage	All stage	Infect. stage only
4733	528	147	11.1	3.1

Eight follow-up surveys by identical methods were made during the second and third years after treatment. Four were negative for third stage larvae. These eight surveys are summarized as follows:

	Number positive for		Percentage positive	
Mosquitoes dissected	All stage larvae	Infect. stage	All stage	Infect. stage only
2052	43	12	2.0	0.58

These results showed a significant reduction of infective stage larvae with $P<0.0005$.

It is also of interest to note that intensive mosquito surveys by this same method performed three and five years following mass treatments with diethylcarbamazine in Tautira, the village illustrated in Table I, showed no infective stage larvae of *Wuchereria bancrofti* in any of the 327 mosquitoes dissected.

Before the filariasis control program was begun in American Samoa, in 1962, intensive mosquito surveys were performed by the same intensive method devised by Bonnet *et al.* (1956) in the four rural villages of Aoa, Amouli, Amanave, and Malaeloa in American Samoa. Follow-up intensive mosquito surveys were completed only in the three villages of Amouli, Amanave and Malaeloa during the third year after completing mass treatment with 72 mg per kg of body weight of diethylcarbamazine. The summaries of dissected mosquitoes yielding infective stage larvae caught in these three rural villages before and three years after diethylcarbamazine are as follows:

		Mosq. with infect. stage larvae	
	Mosq. dissected	No. +	% +
Before diethylcarbamazine	327	7	2.1
Third yr. after	375	2	0.53

It is of interest to note that the percentage of mosquitoes with infective stage larvae dropped from 2.1 per cent before diethylcarbamazine to 0.53 per cent during the third year following mass chemotherapy. It should be noted that fewer mosquitoes were dissected in the three villages in American Samoa than in Vairao, Tahiti, and so the significance level of P falls between 0.10 and 0.20.

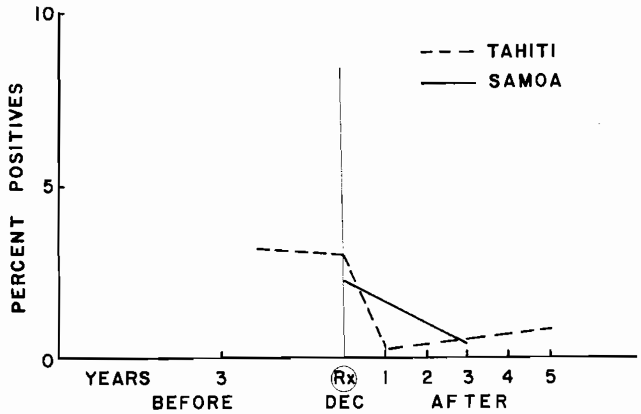

Figure 5—Per cent of mosquitoes with infective stage larvae before and after diethylcarbamazine.

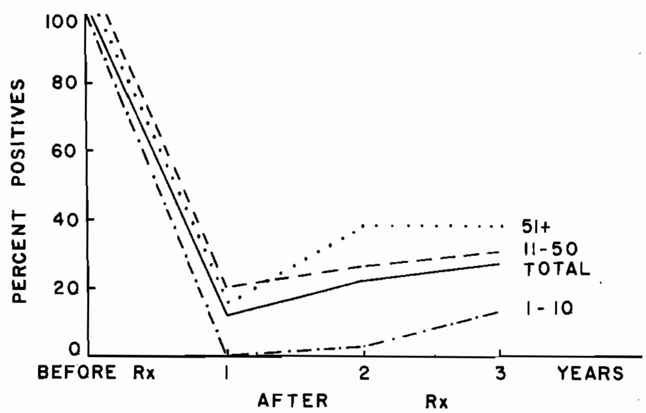

Figure 6—People positive at different Mf. levels before and after diethylcarbamazine.

Figures 6 and 7 show an analysis of microfilaria rates and average microfilaria counts before and during three years after diethylcarbamazine in American Samoa for 145 pre-treatment positive individuals grouped according to their pre-treatment level. The difference observed in percentages positive at three years between the group with low initial count and the group with high initial count was found to be significant at a multiple test level of $P<0.005$ (test on all three between-group differences made simultaneously).

Figure 6 further illustrates the thesis of Ciferri *et al.* (1966), that an important positive association exists between pre-treatment microfilaria density and percentage of carriers found positive after treatment.

Figure 7 shows that recurrences with the highest microfilaria counts are found in the group of people having pre-treatment densities of 51 or over. The difference observed in mean counts at three years between the group with low initial count and the group with high initial count was found to be significant at a multiple test level with $P<0.0001$ (three tests made simultaneously). Figure 7 further shows the average

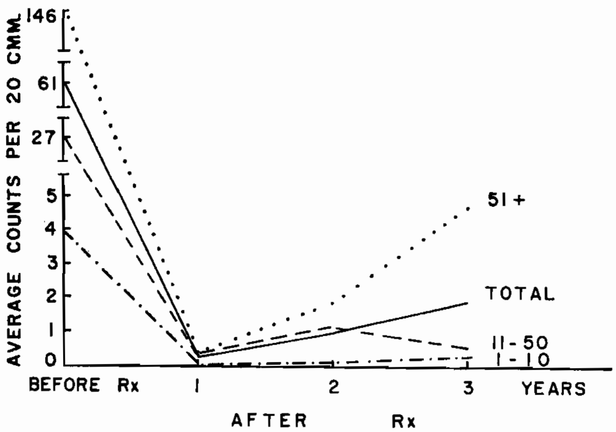

Figure 7—Average counts per Mf. level in people positive before and after diethylcarbamazine.

density of microfilariae per 20 mm³ of blood in the 145 people to have dropped from 61 to 1.8 per positive person (significant at a level $P<0.0001$).

Rosen (1955) in his Table 11, in comparing the susceptibility of *A. polynesiensis* in Tahitian strains of *W. bancrofti*, shows that mosquitoes fed on people with low microfilaria counts, e.g., less than one, are infected less frequently and with fewer larvae per infected mosquito than mosquitoes which were fed on people with high microfilaria counts.

By comparing this information with that in Figure 7, it would be of interest to speculate concerning the minimal microfilaria rates and counts below which interruption of transmission might occur.

In American Samoa in 1965, following the first mass treatment of the whole island of Tutuila with 12 doses of 6 mg per kg of body weight, administered within seven months, it was found, after resting for one year, that three per cent of the population of six rural villages tested were still positive, with an average of 0.4 microfilariae per 20 mm³ of blood per person. Instead of following the procedure previously used in Tahiti, i.e., performing an annual island-wide blood survey and retreating the positives only, it was decided that it would be cheaper and probably more effective to retreat the whole population with 12 doses of 6 mg per kg of body weight at optional intervals during the second or third year after the end of the previous treatment.

Conclusions

Diethylcarbamazine: (a) The success of a mass treatment program with diethylcarbamazine against filariasis is directly proportional to the amount of the drug prescribed and the thoroughness with which it is administered. It must be remembered that, in any control or eradication program on a volunteer basis, human factors, such as "excusals" or "refusals" and migrations of untreated carriers into an area will influence the results.

(b) Apart from the inconveniences of taking repeated doses of the drug and of the reactions resulting from liberation of excess foreign protein from the destruction of microfilariae, the disturbances are few. Control programs here described for Tahiti and American Samoa illustrate the reductions of microfilariae to a minimum in controlled treated groups, using two different total dosage levels. As clinical filariasis, such as lymphangitis and filarial fever, were also reduced to a low point under these treatments and as few new cases of elephantiasis developed in such controlled programs, it appears that the importance of filariasis, as a disease of public health importance, has been greatly reduced.

(c) This does not mean, however, that mass treatment programs with diethylcarbamazine have resulted in eradication of filariasis.

(d) A significant question is whether, by applying greater perseverance in the further controlled administration of diethylcarbamazine, it will be possible to assure more effective administration and consequent lower infection rates, which will eventually result in eradication of filariasis.

Supplement

At the Inter-regional Seminar on Filariasis, of the World Health Organization, held in Manila in November, 1965, Dr. M. Sasa (1966) suggested the plotting of a cumulative percentage distribution of microfilaria positives by probit scale to evaluate the microfilaria load in epidemiologic studies for filariasis.

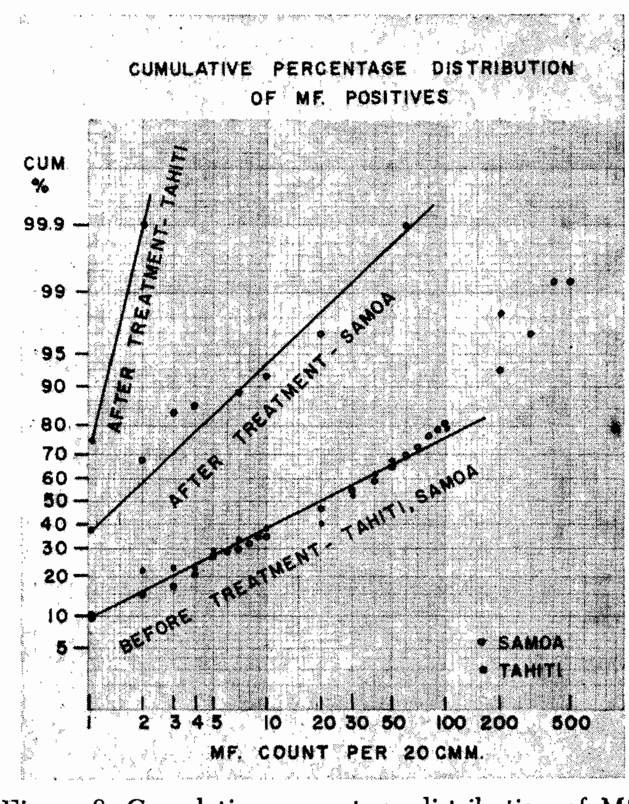

Figure 8—Cumulative percentage distribution of Mf. positives.

Table 3—Summary of data.

	MF rate (% +)	MF density (Average MF counts per 20 mm³ of blood)
Tahiti		
Before	100	56.0
After	13	0.2
Am. Samoa		
Before	100	61.0
After	26	2.0

Table 4—Frequency distribution of microfilaria positive cases by microfilarial counts per 20 mm³ before and after diethylcarbamazine treatments.

Micro-filaria count	Samoa: average dose: 72 mg/kg Before Treatment No.	Cum. %	After Treatment No.	Cum. %	Tahiti: average dose: 156 mg/kg Before Treatment No.	Cum. %	After Treatment No.	Cum. %
1	15	10.3	14	37.8	6	10.0	6	75.0
2	6	14.5	11	67.5	7	21.7	2	100.0
3	4	17.2	6	83.7	1	23.3		
4	5	20.7	1	86.4	0	23.3		
5	9	26.9	0	86.4	3	28.3		
6	3	29.0	0	86.4	0	28.3		
7	2	30.3	1	89.1	3	33.3		
8	3	32.4	0	89.1	1	35.0		
9	3	34.5	0	89.1	1	36.7		
10	1	35.2	1	91.8	0	36.7		
11-20	17	46.9	2	97.2	2	40.0		
21-30	11	54.5	0	97.2	8	53.3		
31-40	6	58.6	0	97.2	5	61.7		
41-50	9	64.8	0	97.2	3	66.6		
51-60	8	70.3	1	100.0	2	70.0		
61-70	4	73.1			2	73.3		
71-80	6	77.2			3	78.3		
81-90	3	79.3			1	80.0		
91-100	2	80.7			0	80.0		
101-200	18	93.1			4	98.3		
201-300	6	97.2			1	100.0		
301-400	3	99.3						
401-500	0	99.3						
501-600	1	100.0						

In Japan during August 1966, Dr. Sasa reviewed the above paper, with the original data, and plotted the information therein from Tautira, Tahiti, and from American Samoa, by this cumulative percentage of microfilaria positives, both before and after treatment. The results are shown in Table IV and Figure 8. They may be compared with Table III which summarizes data from Figures 1, 2, 4 and 7, and records the microfilaria rate and microfilaria density, i.e., average counts per 20 mm³ of blood. by procedures that have previously been used in many filariasis studies.

Both methods illustrate the marked reductions that occur following the close of treatment with diethylcarbamazine by the regimens described in the body of the paper. The studies demonstrate that diethylcarbamazine, if used adequately, is a safe and valuable drug for the control of filariasis.

Albeit, the reports and discussions at the recent Seminar on Filariasis of the Eleventh Pacific Science Congress in Tokyo on August 23 and 24, 1966 still show the need for the discovery and testing of new drugs that can be administered with greater ease and that will destroy both adult filaria and microfilariae more quickly than any drugs now available for use.

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MOSQUITO CONTROL ACTIVITIES OF THE U.S. ARMED FORCES IN THE REPUBLIC OF VIETNAM

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Mosquito control as a weapon against disease has been of great importance to many military camgaigns and perhaps never more so than in the present operation in the Republic of Vietnam. The problems of application have been more difficult and frustrating because of the nature of the war itself, and the inaccessible location of most of the significant disease sources. Much has been written regarding the absence of definable combat fronts and the unpredictable nature of guerrilla tactics, and these conditions affect mosquito surveillance and control as well as all other aspects of the campaign. This discussion is concerned primarily with experience in the First Corps Area of the Republic of Vietnam where major responsibility has been assigned to the U. S. Marine Corps and Navy. The other three corps areas comprise the southern three-quarters of the RVN and are the responsibility of the U. S. Army. The same basic problems are encountered and the mosquito control activities of personnel in each area have been similar.

MOSQUITO-BORNE DISEASE

Mosquito-borne diseases, with the exception of malaria, have not been as serious in Vietnam as had been expected. Dengue and encephalitis are present but little or no filariasis or hemorrhagic fever has been reported.

Dengue.—Although dengue was frequently diagnosed clinically by medical officers, only 8 military cases were reported officially in I Corps during 1966. Very few have actually showed an antibody rise between acute and convalescent sera diagnostic for dengue. Its presence has been reported in other parts of Vietnam by USAID officials and the U. S. Army. The amount of illness diagnosed as "fever of undetermined origin" exceeds that of confirmed malaria, and Army authorities have estimated that one-third or more of this may be dengue. If this is dengue it appears to be much milder than that encountered in World War II. However, the vectors of the disease, *Aedes aegypti* and *A. albopictus* are found commonly thoughout the country.

Japanese B. Encephalitis.—The picture for Japanese encephalitis (JBE) is not entirely clear. USAID health officials reported that the French showed serological evidence of the disease in their troops, but AID had no case data prior to June 1966. Four hundred cases of encephalitis or encephalomyelitis have been observed over a four year period in the civilian population around Quang Ngai. These cases occurred predominantly in the 4-10 year age group from rural areas and there was a mortality rate of about 80%. Additional evidence of viral encephalities, possibly JBE, was obtained when a total of 60 or more cases of viral meningoencephalitis with one death was reported from military personnel in I Corps through November 1966. The incidence went from 2 in June to 22 in July, 10 in August and fell to 5 in September and October. Preliminary serological tests were run on paired sera of 15 of these meningoencephalitis patients; nine of the 15 had significant rises in titer in hemagglutination-inhibition tests to JBE. Since those findings are preliminary it cannot be said for certain that JBE virus is the causative agent. (Preventive Medicine Unit, Naval Support Activity, DaNang, 1966). However, if it is not JBE, then it is probably due to a virus closely related to it. Medical officers have reported that clinically most of the cases have been milder than typical JBE. With the presence of the reported vectors, *Culex tritaeniorynchus*, *C. gelidus* and *C. pipiens quinquefasciatus* in the country, likelihood for more cases of JBE or JB-like encephalitis seems very high. All three mosquitoes were found very commonly throughout the delta and coastal areas.

Malaria.—Malaria and its control is now the most important disease problem occurring in Vietnam. The existence of drug-resistant *Plasmodium falciparum* has been well established. By far the greatest proportion of malaria cases diagnosed in Vietnam are due to *falciparum* malaria. Figures on the exact total number of all malaria cases to date since the buildup are not available but it undoubtedly exceeded 10,000 for U.S. and Korean forces alone by the end of 1966.

The malaria eradication program in RVN followed the standard pattern of residual DDT spraying of houses, malaria smear collections and mass use of antimalarial drugs. This program became ineffective after 1963 because of the war. The Malaria Control Service reported that the Viet Cong made a special target of control spray crews by destroying vehicles, equipment and supplies, and killing personnel. (RVN, 1963). By the spring of 1965 when U. S. Marines began to take up positions in the northern quarter of the Republic of Vietnam, mosquito control had ceased for all practical purposes. Residual spraying of houses was restricted to limited numbers in the secure coastal areas where malaria incidence had never been high. Lysenko (1965) had noted that French medical officers as far back as the end of the nineteenth century recognized that the territory of Vietnam is not homogeneous for malaria. For example, in North Vietnam the Red River delta, the maritime plains and the high mountains have been practically free of malaria while the infection rate in the foothills and medium elevation mountainous areas is extremely high. Similarly, in South Vietnam the coastal plain and much of the delta has little or no malaria while there are numerous hyperendemic foci scattered throughout the interior.

Lysenko divides North Vietnam into four malariogenic zones based on topographical features which in turn determine the distribution and abundance of *Anopheles minimus*. He concludes that the medium-elevation mountain-and-river zone is an independent malaria zone where all human settlements are intensive and constantly active foci and implies that *mini-*

mus is the only significant vector. Malaria in the other zones (low mountain-and-river, hill-and-river, and plateau) is hypoendemic and is dependent upon periodic importation of the carrier and sources of infection from hyperendemic foci. Military experience in the northern part of South Vietnam since July 1965 supports this concept basically. However, there is considerable evidence that, given the presence of adequate parasite reservoir, *Anopheles* species other than *minimus* are responsible for maintenance of transmission.

Organization for a Control Program

The Marines began their development of the DaNang, Hue-Phu Bai and Chu Lai enclaves in March and April 1965. Serious deficiencies in vector control resulted from lack of pesticides, equipment and adequately-trained personnel. Fortunately these deficiencies were not followed by any significant amount of illness because of the low level of vector-borne disease in the localities where personnel were concentrated at that time.

A survey of the situation during July 1965 by the senior author resulted in recommendations for a vector surveillance and control program. Special emphasis was placed on the need for the collection and interpretation of entomological and epidemiological data in order to define high-risk areas and provide priorities for control operations. A prime control measure for implementation by the III Marine Amphibious Force was outlined under the heading, *Personal Protection and Malaria Disciple*. This included command directives, education and regular unit inspections to check on use of suppressive drugs, repellents and bed nets. It was also recommended that helicopter insecticide dispersal units be obtained as soon as possible and that the Armed Forces Pest Control Board coordinate plans to obtain field trials of mosquito control by low volume dispersal of insecticides in selected areas of Vietnam. Other recommendations were made for the revision of tables of allowance and cataloging of pesticides and equipment, and greater emphasis on the training of technical personnel.

U. S. Navy preventive medicine components (G-17 and G-18) began to arrive in DaNang during July 1965 and were assembled to form a Preventive Medicine Unit under the Naval Support Activity. A vector control component (G-19) was soon added which provided valuable assistance in the form of supplementary supplies, maintenance and repair of equipment, training, and direction of large scale operations, including helicopter dispersal. Although disease outbreaks of all types were investigated, the control of malaria became the single most important function of the Naval Preventive Medicine Unit.

Distribution of Malaria in the Republic of Vietnam

One of the most important and successful activities of the Unit has been the epidemiological follow-up of malaria cases which was organized and carried out by the Officer in Charge, LCDR P. F. D. Van Peenen, MC USN and the epidemiologist, Lt. W. T. Adams, MC USNR. A number of techniques were employed to define the hyperendemic areas and insofar as possible to pinpoint the origin of each infection. These included: patient interviews, review of battalion command records showing company and platoon movements, determination of lengths of exposure to infection, and location of probable origin of infection by map grid coordinates. The end result was the identification of problem areas by months, indicated by colored pins on large area maps. Much of the data became available too late for use in current operations but it will be of great value in guiding control programs during 1967.

The nonhomogeneity of malaria in Vietnam has made the use of incidence rates for comparisions between units or time periods rather meaningless. For example some satisfaction might be taken from the reported 9% rate for French troops in 1953 as compared with an approximately 2% incidence in U. S. forces in 1966. However this would be unjustified without information as to the numbers exposed in specific locations. Overall Marine rates have been considerably lower than Army rates but again this comparison is meaningless when complete information on the population at risk and degree of risk in specific areas is not available.

It is necessary to examine each focus of endemicity separately to obtain a reliable picture of the malaria situation. The areas of I Corps in which U. S. forces are concentrated include the three enclaves, DaNang, Phu Bai and Chu Lai, and from July 1966 the area south of the Demilitarized Zone (DMZ), based at Dong Ha. Malaria cases by month for these areas is shown in Table I.

The incidence for the DaNang area has been relatively insignificant although the population at risk has been much larger than in the other enclaves. The terrain is typical of the coastal plain consisting largely of rice paddies with interspersed estuaries, rivers, and small farms. Most of the 18 cases from DaNang appear to have originated in perimeter areas rather than in the main base complex.

At Phu Bai the foothills are much closer to the base area. The rolling hills are covered with dense but low scrub and numerous streams, small rice paddies and seepage areas occur in the valleys. Malaria attack rates have been higher than in other enclaves but the smaller population at risk makes the total considerably less. The majority of the 69 cases from Phu Bai during 1966 originated at only two locations. Twenty cases resulted from one village during a two-weeks occupation for an annual rate of 570/1000 and most of the others from a battalion headquarters position in the foothills. There was a significant reduction in malaria from the Phu Bai enclave during the remainder of 1966 with no cases reported in Marines during the last four months. Insecticide applications by helicopter were initiated in May but it appears that there was also a considerable reduction in personnel at risk throughout the area; therefore there is insufficient evidence to make a positive claim that the absence of malaria was an effect of the insecticide applications.

Another area of high malaria was revealed by a battalion of Marines while deployed for about three months in the Thanh Valley five miles north of Hue. The attack rate for the period of exposure was approximately 360/1000/annum. This is a foothill zone very much like the Phu Bai area.

A base was established at Dong Ha in July to support the extensive operations to the west between Route 9 and the DMZ. Dong Ha is located in the coastal plain and its relationship to the foothills is quite similar to the situation at Phu Bai. Several marine battalions were involved in hard fighting in an area extending about 20 miles inland and north to the DMZ. The key position in this area, nicknamed the "Rockpile" is located at the confluence of five valleys. Topography of this area is best described as medium elevation mountain-and-river. About 300 cases of malaria were reported from operations in this area during the last half of 1966 (Table I, South of DMZ). As expected few if any of these could be shown to have originated at the main Dong Ha base. One battalion showed an attack rate of 956/1000/annum and several others average about 300/1000/annum during operations near the "Rockpile". There is every indication that the great majority of the cases which occurred during the remainder of 1966 originated in the medium elevation terrain just south of the DMZ.

The bulk of the military population at Chu Lai was located in permanent camps along the coast and very little malaria occurred in these locations. A major portion of the 425 cases from Chu Lai listed in Table I originated from semi-permanent battalion positions in the foothill zone just west of the north-south highway or from patrol or sweep operations beyond the outer perimeter.

The most significant conclusion suggested by Table I is that more than two thirds of the malaria cases during 1966 in I Corps appears to have originated at relatively few hyperendemic foci.

The situation outside of the I Corps area during 1966 was similar but on a larger scale. There were numerous endemic foci which consistently produced very high malaria rates while many extensive areas of the country remained malaria-free. In the highlands west of Qui Nhon total malaria cases in Korean forces during 1966 exceeded that for the entire I Corps area. The Ie Drang Valley between Pleiku and the Cambodian border is probably the most hyperendemic area yet encountered in the Republic of Vietnam. Every operation conducted in this valley has resulted in very high malaria attack rates. A 10-day sweep in August 1966 produced 485 cases representing 20% morbidity for a rate which in less than two months would have given 100% infection. Another unit averaged 10 cases per day in September even though it was on the new suppressive drug, DDS (diamino-diphenylsulfone).

The pattern of ever-increasing transfers of parasite reservoirs from hyperendemic, independent malaria foci to all parts of Vietnam and beyond became obvious during 1966. Montagnard refugees and large numbers of Vietnamese Army personnel brought into the Duc My-Lam Son area from all over Vietnam for training undoubtedly played a major part in the high malaria incidence which developed there during the last half of the year. Fifteen cases occurred in Korean personnel during October at Chu Lai less than two weeks after transfer from their division headquarters more than 200 miles to the south. There were over 200 cases on Con Son Island during May and June where prior to 1966 only a few had been reported. This abrupt development of a malaria problem suggests the intro-

Table 1. I Corps - malaria cases by month for 1966 in the Republic of Vietnam.

	TOTAL	DANANG	PHU BAI	CHU LAI	SOUTH OF DMZ	OTHER
JAN						
FEB	76	?	12	18-?		46*-?
MAR						
APR	50	?	35	9-?		6-?
MAY	81	2	3	10		66**
JUN	69		10	30		29**
JUL	73	3	4	47	10	9**
AUG	142	0	5	54	73	10**
SEP	122	3	0	51	66	2
OCT	224	7	0	114	102	1
NOV	81	2	0	40	39	0
DEC	68	1	0	52	9	6
TOTALS	986	18	69	425	299	175

*Mostly from inland operations

**Mostly from Thanh Tan valley

duction of a substantial reservoir in the several thousand prisoners transferred to the island in recent years.

Two cases of introduced autochthonous malaria occurred in civilians who had never left Guam in November 1966 and were traced to two U.S. Army Guamanians on leave from Vietnam.

Vector Surveillances.—The necessity to obtain good information on species present, abundance, breeding sources and habits in order to conduct an effective program is obvious to all mosquito control workers. This was the primary mission of the entomology section of the PMU.

The problems associated with establishing a unit in a war zone were for the most part the same as those encountered in similar campaigns of the past. Although entomological investigations began immediately, building a firm base of operations overshadowed all initial activities. The greater part of the first six months in the country were taken up with overcoming such basic inadequacies as lack of suitable laboratory facilities, basic equipment, keys to the mosquito fauna, shortage of personnel, and lack of experience. Despite these difficulties considerable information on mosquito bionomics was obtained.

Some 12 genera and 76 species, or about 45% of the mosquito fauna known to occur in South Vietnam, were encountered in I Corps and significant information on bionomics was obtained (Santana et al, 1966).

Anopheles minimus minimus is historically the most important single malaria vector throughout most of southeast Asia. It has been reported that in Vietnam malaria occurs wherever it is found while the species is rare in nonmalarious areas (Morin, 1935), (Toumanoff, 1936), (Lysenko, 1965). In China *A. minimus* is extremely anthropophilic and endophilic and according to Ho Ch'i, its sporozoite rate is the highest of all *Anopheles*. It is extremely susceptible to household residual spraying and has been virtually wiped out in areas where this program has been in effect for several years (Ho Ch'i, 1965). *A. minimus* larvae have been collected in small numbers at Lang Vie, the Rockpile, in the hills west of Chu Lai and in the Qui Nhon area. It has rarely been taken in the night biting collections even in areas where malaria attack rates for military personnel were high. This may be explained by its strongly endophilic habits.

Anopheles balabacensis balabacensis is exophilic and is probably an even more efficient vector than *A. minimum* (Scanlon and Sandhinand, 1965) but fortunately its distribution range is limited in I Corps. It is likely that *A. balabacensis* will be found in areas with high attack rates, such as forested localities near the "Rockpile" or in the Ie Drang Valley, but collections in these areas as yet have not been made or had not been reported by the end of 1966.

Surveys conducted i n I Corps areas where military malaria attack rates have been high have not shown a significant *A. minimus* population, and *A. balabacensis* was not found at all. This raises the question as to which vectors are responsible. *A. jeyporiensis candidiensis* is often referred to as an important primary or secondary vector in Vietnam, and this species has been taken frequently in most areas where malaria cases have occurred. *A. maculatus* and *A. aconitus* have also been reported as potential or secondary vectors in Vietnam. All three have been taken in larval surveys and light traps from endemic areas but *A. aconitus* has been found more frequently than others in the Chu Lai area. Navy entomologists, medical officers and technicians made night-biting collections from themselves during 1965 and 1966 in I Corps. Data is available from 18 locations representing 80 hours on 31 nights. The following consolidation shows numbers of significant *Anopheles* species collected in localities with low to high malaria rates compared with those from which no cases were reported:

	Malaria Present	*Malaria Absent*
minimus	0	0
balabacensis	0	0
jeyporiensis candidiensis	6	0
maculatus	9	0
aconitus	9	0
philippinensis	3	3
sinensis	28	30

Several diverse items of information developed during the past year and a half suggest that *A. aconitus* may be a very important vector of exogenous malaria. In July 1966, the Army 20th Preventive Medicine Company found three out of 20 dissections of *A. aconitus* from Con Son Island positive for sporozite or oocysts. Sixty-eight specimens of *A. aconitus* were taken in human biting collection in 4 nights, of which only 10 were indoors. In September oocysts were found in 3 of 20 *A. aconitus* collected in the Duc My area (Willman, 1966). During 1966 the U. S. Army Medical Component, SEATO Laboratory entomologists also found *A. aconitus* specimens from Thailand positive for malaria parasites (Gould, 1966).

No references to *A. aconitus* as a primary vector of malaria in Vietnam have been found and *A. maculatus* and *A. joyporiensis candidiensis* are usually reported as secondary to *A. minimus*. However, the ecological changes brought about by the war situation are fully compatible with a shift in relative importance from the strongly endophilic *A. minimus* to these more exophilic species. The provision of large numbers of human hosts in feral environments, together with an absence of large animals, would provide an idea situation for transmission of malaria by normally zoophilic and exophilic vectors.

Anopheles sinensis is the most common *Anopheles* in Vietnam, particularly in the coastal plain. Despite the presence of large populations of this species malaria rates have remained very low. Presumably this is due to its inefficiency as a vector and the small parasite reservoir which has prevailed in the coastal parts of Vietnam. Certainly it has been responsible for endemic vivax malaria in many countries of Asia and for temporary outbreaks in plain and delta regions of North and South Vietnam. The efficiency of *A. sinensis* as a vector of *falciparum* malaria is unknown. As the reservoir in U. S. and allied forces builds up with continued introduction from the interior, we may expect increased transmission in the coastal plains by *A. sinensis* unless effective control of this species is obtained. Continued high incidence of malaria during the closing months of 1966 and the increasing percentage of vivax may be an indication of future trends.

Control

Mosquito control by military units in Vietnam falls into three categories: personal protection, adult and larval ground control operations and aerial dispersal. Personal protection includes the use of repellents, nets and screens, and protective clothing, and in the case of malaria the use of chemoprophylaxis. Thus far repellents and suppressive drugs have been the only practical measures which could be used in the advanced combat-type situations where most of the malaria has originated. Serious deficiencies in application have reduced effectiveness greatly, probably by at least one-half. These deficiencies are primarily due to drug resistence, failure to use repellents and anti-malaria tablets, and at first, nonavailability of repellents to some units.

Anti-malarial Drugs—The existence of a large amount of drug resistance has been conclusively demonstrated by clinical experience in several military hospitals. A study of 89 cases of *falciparum* malaria in personnel from Vietnam by CDR F. M. Barnwell at the Naval Hospital, Guam, from September through November, 1966, suggests that the problem of drug resistance may be far more serious than yet realized. Only three of the 80 patients were returned to duty as cured, despite treatment regimens which included one or more of the usual medications, chloroquin, pyrimethamine, quinine, sulfa, and DDS, and the experimental Fanasil. Total relapses under eight different treatment regimens ranged from 88 to 100%. It should be emphasized the relapse rate includes all individuals with parasitemia whether or not clinical symptoms were present. One of the most interesting findings was the very high percentage of asymptomatic parasitemias and the benign nature of the symptoms when present. In fact, 21 patients admitted to the hospital by transfer from Southeast Asia with diagnoses other than malaria were found to have positive smears. Other military hospitals have not encountered such high relapse rates, but significant amounts of asymptomatic malaria have been noted in several unit surveys by the U. S. Army WRAIR Unit at Siagon.

Duplication and confirmation of the Guam findings will be necessary before concluding that they signal the future development of a widespread condition. However, biologists who are familar with the history of insect and bacterial resistance to chemicals will recognize a pattern and, given the mass use of anti-malaria drugs throughout Southeast Asia, will not find such a development illogical.

The CDC reports a ninefold increase over 1965 in the number of malaria cases of military origin with onset in the U.S. through October, 1966. The cumulative total for malaria with onset in the U.S. as of December 31 is given as 517. It is not known whether these resulted because of failure to maintain the chloroquin-primaquin prophylaxis for the required eight weeks after leaving a malarious area, or because of drug resistance, or both.

Repellents.—The lack of repellent was certainly an important factor in many units during the first year. However, the conclusion that non-availability was the primary cause of failure to use repellent would be a mistake. Assurance of a plentiful supply would not solve the problem in itself because it is quite evident that even when repellent was on hand it was used for the most part only when pest mosquitoes were abundant. Numerous night biting collections have demonstrated that the *Anopheles* vectors are most active after 2100 hours. The bite of the *Anopheles* is hardly noticed by most people even when awake. An abundance of pest mosquitoes just after sunset will cause a run on the repellent supply, whereas when pests are not annoying there is no concern or even realization that *Anopheles* mosquitoes are present and very little use of repellent.

Another factor which has limited use of repellent has been the unfounded, but widespread rumor that the Viet Cong could detect the odor. Special forces and Marine trainees have actually been told by their instructors that they should not use repellents for this reason. Fortunately, timely, controlled tests at the U. S. Army Medical Component, SEATO Laboratory and by the USDA at Gainesville showing that the odor of the standard repellent cannot be detected unless it is within 12 inches of the nose, have provided information to combat this fallacy.

Other considerations which may explain in part the failure to utilize personal protection methods more fully are inadequate education and an indefinable attitude sometimes referred to as "combat fatigue". There is no doubt that more training in malaria discipline can and must be accomplished at all levels and that continued emphasis on command responsibility is essential. It is also a fact that an undetermined number of personnel, particularly during or after long and repeated exposure to conditions where immediate survival is at stake, have little concern about a possible malaria attack.

Control Operations

While aerial treatments are sufficiently hampered by hostile action, ground treatments are precluded by it. Some "secure" areas where ground treatments have been employed have had pretty small perimeters, it is true, but the security is a necessary prerequisite to ground actions. This has meant that in some places adulticiding, without larviciding or source reduction of any nature, has been the method of the limited choice; use of large equipment, such as turbines, has been confined to roads with good, solid foundations beneath them, and good drainage.

Fortunately, some ground equipment has fitted this specialized situation. The most useful, probably, is the back-pack, engine-driven mist and dust blower, with which a very considerable coverage can be effected in areas accessible only on foot. A nonthermal fog generator which was developed by the military, has been an effective area treatment tool, even though it is trailer mounted.

There is now being built up in each major area a nucleus of engineering personnel, trained in the proper use of both large and hand-operated equipment and coordinated closely with medical department surveys of breeding sources and population levels. The problem, therefore, is principally centered about the protection of the patrol, the civic action detail and similar isolated units or individuals, operating away from the camps and military enclosures.

It was obvious as early as July 1965 that conventional ground control methods would not be applicable to a majority of situations where malaria was likely to be most prevalent. Therefore recommendations were made for the provision of a helicopter capability as soon as possible as well as for field trials in RVN of the low volume dispersal concept.

The Navy Bureau of Medicine and Surgery arranged for two helicopter dispersal equipment experts to report to the Preventive Medicine Unit, Naval Support Activity, DaNang, in order to train vector control personnel and aircraft crews in the use of HIDAL (conventional liquid dispersal) and HIDAF (fog). Mr. David L. Hayden and Mr. Willie V. Weeks of the Navy Disease Vector Control Center, NAS, Jacksonville arrived at the end of November and a helicopter dispersal capability was established by 15 December.

Pre- and post-treatment data from larval dipping stations were used to evaluate effectiveness of HIDAL in Chu Lai area when operations began in February 1966. The survey data demonstrated excellent control of larvae but it has not been possible to prove that there was a similar effect on malaria rates because of several unknown factors such as seasonal incidence, population at risk, delayed incubation period, etc. The small payload and limited helicopter availability prevented the regular applications to sufficiently large areas which would have been required to demonstrate effective control of malaria. Nevertheless, there were definite indications that rates were reduced in treated zones at both Chu Lai and Phu Bai. The most serious weakness of the HIDAL system is the small payload and necessity to restrict operations to fully secured areas. These deficiencies were responsible for the failure to conduct complete treatments at Chu Lai and at the "Rockpile" and other high risk areas. The assignment of adequate helicopters, pilots, technical direction and crews was not possible during 1966 because of the demands of combat operations.

The Army has utilized another type of equipment for dispersal of a medium low volume (57% malathion at 8 to 13 oz./acre) spray from the HU-1 helicopter. This is a commercial unit which incorporates the tank, pump and booms in one unit and does not require any modifications or attachments to the helicopter. The payload is 4 to 5 times that of the HIDAL but the same vulnerability to enemy fire also prevents its use in combat or insecure zones. Definitive, objective data for evaluation of effectiveness against *Anopheles* species has not been available although subjective observations indicate good results against adult mosquitoes. Results in terms of lower malaria rates in treated areas were also inconclusive as of October, 1966.

Attempts to obtain the use of a C-123 aircraft to conduct field trials of ultra-low-volume applications against *Anopheles* of Southeast Asia were unsuccessful until late in 1966. A capability was finally established in October when the Commander of U.S. Forces in Vietnam requested assistance from the Special Aerial Spray Flight. Major C. W. Marshall, USAF, and Major C. T. Adams, USAF, on TDY from Langley AFB, trained pilots and crews in the conversion of defoliation equipment for insecticide application and in the techniques of low volume applications. One C-123 was assigned for a period of 30 days for the purpose of training and operational trials. Several areas were treated in Vietnam but adequate entomological surveillance facilities which could be used for meaningful evaluation were not available in most locations. One limited study was conducted on Con Son Island where 57% malathion at a dosage of 0.5 lbs/acre was applied. Data collected under the direction of LT. COL. T. E. Blakeslee, U. S. Army indicated very good post-spray reduction of both larvae and adult mosquitos over a 10 day period when compared with pre-spray counts, while counts in untreated areas increased considerably. Evidence of a reduction in malaria attack rates was not expected and was not obtained because of the lateness of the season and short period the aircraft was available.

Plans are being developed for extensive utilization of low volume dispersal by the C-123 during 1967 and strong recommendations have been made to improve facilities and provide more specialized personnel for the collection and analysis of epidemiological and entomological information.

Repeated swath runs in a grid pattern over enemy held territory presents an unacceptable risk even with the C-123. Therefore control in such areas will continue to be a problem. Some consideration is being given to the possibility of treating such areas by irregular single swaths to reduce vulnerability. An important known is how complete coverage must be to reduce vector populations below a critical transmission level. LV dispersal equipment for use on high performance combat aircraft has been under development at the Navy Disease Vector Control Center, Alameda and it is hoped that operational trials in Vietnam will also be possible with this equipment during 1967.

The failure of household residual techniques to control exogenous malaria in RVN and other countries of Southeast Asia as well as the urgency of the malaria problem facing friendly forces, make a comprehensive evaluation of the low volume concept of the utmost importance. Even if low volume applications are proven to be completely effective against *Anopheles* mosquitoes in protected situations there will be many questions to be answered. There is no prior experience with this method of malaria control on which to determine the frequency of application, most efficient insecticide, selection of target areas and many other problems.

SUMMARY

1. Malaria is by far the most important mosquito-borne disease affecting personnel of the armed forces in the Republic of Vietnam. The total number of confirmed cases in U.S. Forces in less than two years has exceeded 10,000.
2. The distribution of malaria in RVN is highly discontinuous. Incidence is very low in most of the coastal plain, the cities and delta, whereas in parts of the foothills and highlands the attack rate has attained the equivalent of 100% infection in two months for small units. A very high percentage of the malaria has originated in combat, patrol and outpost situations where conventional mosquito control operations have not been possible.

3. Most of the military malaria is contracted outdoors rather than outdoors and there is considerable evidence that the endophilic *Anopheles minimus* has not been a significant vector. The exophilic species, *A. aconitus, A. maculatus, A. jeyporiensis candidiensis* (and in limited areas *A. balabacensis*), are believed to be the most important vectors affecting military personnel.

4. The application of personal protection control methods has not been adequate. Anti-malarial drugs have not provided satisfactory control, primarily because of resistance, and repellents have not been used consistently by personnel during exposure in high risk areas. There is evidence of a marked increase in the prevalence of strains of *falciparum* malaria resistant to *all* anti-malarial drugs

5. The extraordinary amount of personnel movements is causing a redistribution of malaria from the hyperendemic foci of the interior to all parts of RVN and beyond. Wherever suitable vectors occur malaria has increased as new reservoirs are established. At least two cases of autochthonous malaria introduced from Vietnam have occurred on Guam. A major portion of the 517 cases of imported malaria reported in the U. S. during 1966 originated in Vietnam.

6. Conventional mosquito control methods for larviciding and adulticiding are being applied extensively in all the major enclaves and secure permanent bases. This program will assist greatly in the control of mosquito-borne encephalitis and dengue in these areas. It will also assist in preventing secondary vectors, particularly *A. sinensis* from entering the malaria reservoir.

7. A limited capability for low volume dispersal of insecticide by aircraft has been established recently in RVN. Efforts are being made to obtain Department of Defense support of a high priority for development of this technique and its evaluation as a malaria control method during 1967.

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PANEL: OPPOSING PHILOSOPHIES IN MOSQUITO CONTROL TECHNOLOGY

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EMPHASIS ON CONTROL OF ADULT MOSQUITOES IN FLORIDA

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The mosquito problem of any geographical region is intimately related to the natural features of that region—geology, topography, climate, precipitation, and flora being some of the more obvious features of importance. Some understanding of these factors is essential to an understanding of the mosquito problem of an area and the formulation of the most effective and economical system of mosquito control. Because these natural features and the mosquito problem vary from one region to another, procedures for control also vary between regions. A discussion of these "opposing philosophies" of mosquito control for several regions of the United States is the aim of this panel. It is not meant to imply that there is disagreement between the speakers but rather that the emphasis on certain methods vary between the several regions represented. However, it might be useful to state here that primary emphasis is, or should be, on source reduction in almost any community mosquito control program. This is certainly true in Florida where the bulk of state matching funds is earmarked for this purpose. To this extent, the title of this presentation as listed in the program is somewhat misleading. The emphasis on adulticiding in reference to the Florida program refers only to the use of pesticides. It is also recognized that the most effective mosquito control is that which prevents adults from emerging, namely, water management and larviciding, where these methods can be applied effectively and economically. Then why does adulticiding play such an important role in the Florida program? It is necessary to examine the basic characteristics of the problem to explain this.

Geology

The land mass known as the State of Florida is the presently emerged portion of a much larger geographic unit, the Floridian Plateau, most of which is presently submerged beneath the waters of the Gulf of Mexico and the Atlantic Ocean. According to geological accounts (Cook, 1945) this plateau, which is 500 miles long and 250 to 400 miles wide, is an extension of the Coastal Plain of Georgia and Alabama. The highest elevation in the state is just slightly more than 325 feet above sea level.

More than half of the state is composed of the topographical region known as the Coastal Lowlands. This is a flat, low plain extending from sea level to 100 feet elevation around the eastern, southern, and western sides of the state. This broad, flat plain varies in width from about 10 miles at Pensacola to 125 miles at the southern tip of the peninsula and 30 miles at Jacksonville.

The Coastal Lowlands are composed of four marine terraces left by receding seas of rather recent times, the last and most extensive being the Pamlico Terrace, which has a shoreline at 25 feet above present sea level. This vast coastal plain is composed almost entirely of sand near the surface, except in the Everglades and Big Cypress Swamp at the southern tip where bare sandy limestone, muck, or peat lie at the surface. The Florida Keys are composed of limestone or coral with very little or no soil at the surface.

The Coastal Lowlands border the Central Highlands or "Ridge" and the Western Highlands, which are geological extensions of Georgia and Alabama and are composed primarily of clay or sandy, rolling hills interspersed with hundreds of lakes and swamps, many of which were formed by solution sinks in the underlying limestone.

Climate

Average annual temperatures range from 67.6 in North Florida to 77.7 at Key West, and average annual rainfall is from 39.99 inches at Key West to 66.31 inches at DeFuniak Springs in West Florida (U.S. Dept. Commerce, 1962). The record maximum precipitation for a 24-hour period is more than 20 inches.

Mosquito Prob'ems

Owing to their flat relief and recent ori in the Coastal Lowlands have few major streams and have an almost impervious hardpan layer at a depth of about 2 to 3 feet in many areas. These features together with a high annual rainfall during the warmer monts result in poor drainage and dense vegetative growth.

According to Philen and Carmichael (1956) Florida has 8,426 miles of tidal shoreline, about 3½ times the distance from Washington, D.C., to San Francisco. These authors also state that 15% of the area of the state or 5,900,000 acres is marshland and of this, 700,000 acres are capable of producing salt-marsh mosquitoes.

Throughout the state there are 67 known species of mosquitoes, occupying every conceivable kind of water habitat: ground water in the holes of land crabs, bromeliads, tree holes, ponds, lakes, swamps, roadside ditches, man-made containers, and vast areas of salt and fresh-water marshes.

While most of the important species do breed to some extent throughout the state, the obvious exceptions being the salt-marsh species, the flat coastal region is the principal source of floodwater species, *Aedes taeniorhynchus* and *Ae. sollicitans* in the salt marshes, and *Psorophora confinnis*, *Aedes vexans*, *Aedes infirmatus*, and *Ae. atlanticus* in fresh water. *Anopheles*, *Culex* and *Mansonia* also are important in the Coastal Lowlands. *Culex nigripalpus*, an encephalitis vector, is very abundant throughout the lowlands of central and southern Florida.

Vegetation

The salt marshes that encircle the southern half of the state are tangles of mangrove and pickleweed which almost defy penetration by land, and hide the shallow floodwater from aerial view. Adjacent to the salt marshes are dense jungle growths of cabbage palmetto, live oak, vines and other dense vegetation beneath which are uncountable numbers of swales and potholes. Except for the Everglades, which is one vast marsh of hundreds of square miles of sawgrass, the remainder of the Coastal Lowlands generally are covered with dense pine forests having an understory of saw-palmetto and native grasses. The pine forests are interspersed with shallow cypress ponds, potholes, and depressions. There also are large cypress and hardwood swamps distributed throughout the low pine lands.

In the central and western highlands where the rolling land is interspersed with deep lakes and swamps, the principal mosquitoes are various species of *Anopheles*, *Culex*, and *Mansonia*. In central Florida large freshwater marshes produce countless numbers of *Mansonia* mosquitoes, for which there is no effective larvicide.

Rainfall Patterns and Mosquito Production

Except for the deeper swamps, tidal marshes, and streams, the vast lowlands of Florida usually become quite dry in the spring, which is the normal dry season. Heavy local rains usually begin in June or July, suddenly flooding countless shallow depressions over many square miles of the lowlands. If the rains are frequent and general, keeping the depressions well filled, the potential breeding areas of floodwater mosquitoes are greatly reduced. But if the rains come intermittently, causing the depressions to dry up and be reseeded with new batches of mosquito eggs between floodings, results can be catastrophic. General rains associated with storms in late summer and fall can produce floodwater mosquitoes across the entire southern portion of the state at the same moment from the Gulf to the Atlantic.

Tide Broods

Tides play an important part in the salt-marsh mosquito cycle. On the east coast, salt marshes normally are flooded by tides only from September through December, thus the mosquitoes in these marshes usually are produced by local summer rains. However, if rainfall in late summer is below normal, allowing the salt marshes to become dry for a period of several weeks just before the first flooding tide, the marshes become "time bombs" of uncountable mosquito eggs distributed throughout the marsh and ready to hatch within a few minutes of flooding. If the first high tide of the fall occurs with the marshes in this condition, all of the marshes throughout a county or many adjacent counties can become a writhing mass of mosquito larvae simultaneously. Mosquito-eating fishes have a field day under these conditions, but the supply is so much greater than their capacity to consume that the mosquitoes which they destroy cannot be missed.

In many areas of the Gulf coast, tides play a different role in mosquito production. Here the highest spring tides occur from April to September, keeping a large percentage of the salt marshes flooded so frequently that floodwater mosquitoes are able to breed only at the higher levels along the periphery of the marsh.

Other Factors Affecting the Mosqu.to Problem

No general description of the Florida mosquito problem would be complete without mention of the flight habits of the salt-marsh *Aedes* and the location of population centers to the most prolific mosquito breeding areas.

Aedes taeniorhynchus, which comprises about 95% of the salt-marsh *Aedes* in southern Florida, are capable of dispersing 25 miles or farther from the area of hatch (Provost, 1957). This means that large numbers of this species can, and apparently sometimes do, invade communities that are far removed from their point of origin, possibly even in a different county. There also is evidence of other species moving long distances from the breeding sites, but data supporting this are not available.

With this brief, general description of the mosquito production, consider at this point the location of some of the principal centers of population in Florida — Daytona, Cape Kennedy, Palm Beach, Ft. Lauderdale, Miami, Ft. Myers, Sarasota, St. Petersburg and Clearwater. All of these population centers are located astride the vast salt marshes of the state.

Complete Control With Larvicides Not Practicable

It should be clear from this brief discussion that no average mosquito control district can hope to have enough personnel to detect adequately all of the mosquito breeding under these conditions or afford to own a sufficient number of boats, trucks, and/or airplanes, or purchase enough pesticides to control mosquitoes adequately only with larvicides within the short period of about five days that these mosquitoes are in the larval state. Also owing to the physical features of many of the breeding areas, the more costly granular larvicides must be used because the relatively inexpensive larvicidal sprays are not effective in the heavily vegetated breeding areas.

The alternative is supplemental use of adulticides for protecting population centers. Florida learned from experience many years ago that you cannot keep tourists coming back year after year on a promise that the mosquitoes won't be so bad 5, 10, or 20 years from now when the source reduction program has eliminated the breeding areas. A state with a billion dollar tourist industry can't have excuses and it can't afford mosquitoes in abundance where people are concentrated. The potential value of killing adult mosquitoes that are infected with disease agents must also be considered. Malaria eradication is based on this principle. Intensive thermal fogging was the principal method available for combating the outbreak of St. Louis encephalitis in the Tampa Bay area of Florida in 1962, and the massive aerial spray program applied at Dallas, Texas, during the encephalitis outbreak of 1963 was aimed at adult mosquitoes as well as larvae.

These are the reasons why adulticides are used extensively in this semi-tropical playground and will continue to be used for control of pest mosquitoes and disease vectors until the source reduction program has reduced the problem down to larviciding-size. This goal has been attained in some districts, as will be discussed below.

Resistance

The reliance that must be placed on adulticides also is the basis for the philosophy in Florida that the chemicals which are so vital to the state's control program must not be jeopardized by using them as larvicides. Florida simply cannot afford resistance to the adulticides available for this program if there is a logical way to delay or prevent it. This philosophy has served the state well for the past 10 years. There are some spots of malathion resistance in the state after 10 years use, as will be reported by Dr. Rathburn later in this program, but this chemical appears to be effective over most of the state even today. There is no known resistance to naled or fenthion or any other organophosphate in Florida.

Use of Larvicides Increasing

Some control districts have reduced the breeding potential to a size where larvicides can be more effective and the trend is toward increased use of this method in these areas. The only recommended larvicides are granular Paris green and No. 2 diesel oil. It is expected that about 1,000,000 pounds of granular Paris green will be used in the state this year. Generally, larvicides are applied only to those breeding areas within about a five-mile radius of population centers. While this has no effect on large broods of salt-marsh *Aedes* or *Psorophora confinnis* which apparently sometimes infiltrate population centers from sources far beyond this distance, it frequently eliminates nearby broods that otherwise would overwhelm local communities. The value of larvicides is appreciated in Florida and this method will be used more in the future as the production areas are further reduced by water management. In the meanwhile, the effective use of adulticides in and near populated areas must be given a high priority for protecting the best interests of the state.

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SOURCE REDUCTION THROUGH WATER MANAGEMENT

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On examining the topics for discussion this afternoon, the objective of the panel apparently is to present the various philosophies of mosquito control. In discussing source reduction by water management we represent the views of New Jersey and similar states which are temperate regions, having a combination of upland and salt marsh mosquito problems and rainfall generally exceeding man's demand. At the same time, we recognize that water management is practiced successfully in other areas of the country, sometimes with different equipment and sometimes to solve mosquito problems different than those we encounter.

The problem of mosquito control can be based on the fact that two species of animal, i.e., man and the mosquito, require water to live. This is not surprising since all biological organisms require a certain amount of water in their environments, and there is as yet generally sufficient water supply so that man and mosquito do not compete for its use. This problem, then, that man and the mosquito need water but man doesn't need or want the mosquito, has lead to possibly the oldest solution for controlling the mosquito, i.e., managing or manipulating water so that he has enough for himself but as little as possible which is suitable for the mosquito. This is the basic principle on which water management has developed; today we define water management as any procedure used to manipulate excess standing surface water so that it doesn't remain suitable for mosquito development.

It is uncertain just where water management was first practiced. Possibly it occurred when someone recognized that the biting mosquito spent part of its life in water. In the United States water management was being practiced in the early 1900's, a time when the capacity of mosquitoes to transmit disease was first widely recognized with Spanish American War Veterans, returning to the States knowing of such diseases, and also the public pressing for mosquito control measures at home.

It was a time, unfamiliar to us today, when society was not fully mechanized and even health department services were horsedrawn. It was a time when people banded together to form small local organizations to combat the mosquito problem. Editorial cartoons in newspapers, while finding humor in the plight of mosquitoes about to be controlled by filling of creeks, subtly seemed to doubt that such measures could noticeably alleviate the nuisance of mosquitoes. It was a time when the salt marsh was recognized as a major source of mosquito nuisance. Few chemicals for control were yet known and oil was mainly an urban tool for mosquito control. But on the tidal marshes, it was technically impossible to deliver and apply the oil; in addition, oil in such extensive areas would be a fire hazard, cause plant damage, and so-called "loose oil" could not be tolerated on the marshes. Conditions actually dictated the choice of water management for mosquito control. Looking back at the situation, it is probably fortunate that during this period the insecticides and equipment of today were not available to cloud the basic issue of mosquito control, i.e.; the management of excess standing surface water. Initially equipment for ditching consisted of sod cutters and two-man spades handled by laborers. Eventually large machines were developed, e.g.; the Skinner machine, the State machine. Subsequently over the years more efficient machines, e.g.; Backhoe, Crane, Gradall, appeared not only for use on the large acreage of salt marsh but also on upland areas.

Since the 1900's water management has developed, until today it consists of three basic principles of water manipulation: (1) eliminate the water by draining or filling (2) keep the water circulating and (3) maintain the water in a manner unsuitable for mosquito development.

The first of these principles depends on the simple practice of ditching to sufficient depth and slope to encourage draining of water. It has its major application in the plains of rivers where the flood plain and berm or bank of the river is ditched for drainage. Another example of simple drainage for reducing mosquito production is the elimination of permanent swamps, whose clay bottoms prevent percolation, and where the rate of water evaporation and leaf transpiration is insufficient to eliminate the water. Whether these examples employ cuts into the terrain as in the salt marsh or concrete inverts in the uplands, the principle is still one of eliminating water. The best known example of drainage, of course, is the storm sewer system of the city. In congregating surfaces, e.g.; roofs, streets, and sidewalks, which do not absorb precipitation, man has been forced to construct this system to eliminate the excess water not wanted in his immediate environment. Isn't it ironical that in the design of this system to keep it functioning, a "pot hole" of water often is necessary, namely the catch basin.

The principle of drainage is not always concerned with large volumes of water, but also small volumes as, for example, the emptying of paint buckets, tire casings, small unused plastic swimming pools, and the cleaning of clogged roof gutters.

The second principle of water management is water circulation, relying on the fact that moving water generally is not conducive to mosquito breeding. One example is the practice of designing a system of salt marsh ditches in such a manner as to take advantage of the periodic flushing action of low and high tides. This can be either a natural circulation of water without using tide gates, or, with the use of tide gates, circulation can be controlled and tides may flood from one side of a marshy area and then drain off from an opposite side. Since the efficiency of these practices sometimes relies heavily on the ability of predaceous fish to enter the ditches, the practices are not only water management but also applied biological control. Very similar to this is stream clearance which is directed towards maintaining water circulation or drainage of side pools particularly at times of low water levels. Although these methods generally involve circulation of large quantities of water, certain water management methods involve mainly surface circulation or movement, such as wave action. Fortunately for man, most species of mosquito larvae need to rise to the water surface and remain at rest there for air and, in the case of anophelines, for food. The practice of removing vegetation and maintaining clean, narrow edges of bodies of water often insures the surface water movement necessary to prevent mosquito development.

The third principle concerns those cases where man finds it necessary to maintain water. We keep water reserves for life, sanitation, industry, and power. Be these reserves for potable water, for irrigation, for sanitation, or for power, as long as accessory practices, such as elimination of vegetation by burning, herbicides, and clean edging, accompanied by steep banks and periodic fluctuations of the water level, are followed, the water is not suitable for mosquito development.

Often we maintain bodies of water because it is impossible or impractical to eliminate excess water by drainage, due to insufficient gradient in the terrain to make drainage feasible; instead it is necessary to impound the water. If this is a salt water impoundment, the water cover is maintained to the degree that the flood water species, *A. sollicitans*, disappears. If upland drainage is impossible, fresh water may be impounded, sometimes in the form of reservoirs or recharge basins, the sandy floors of which allow percolation and replenishing of the water table. Here again, if accessory practices are followed, there should be no problem. It is only when impounded waters are mismanaged during their use and allowed to remain suitable for mosquito development that the practice of impounding water seems to fail in mosquito control.

These three practices, eliminating, maintaining circulation ,and impounding, form the core of the concept of water management. In many areas of the world, additional procedures have been developed to supplement the water management for multiple purposes in conservation.

In New Jersey with the passage of time, water management procedures have become more firmly established as basic for mosquito control. The main reasons for this are:

1. The high economic value of adjacent areas justifies the highest quality of mosquito control.
2. Water management and ditch systems permit a progressive attack and long lasting, effective control.
3. Maintenance is required only at relatively long intervals, and prevention of the nuisance is achieved.
4. Such systems take advantage of biological control of mosquitoes by fish and avoid hazards of objectionable chemicals.
5. Such systems alleviate stagnation and limit the spread of undesirable waste waters.
6. The long work season permits efficient employment of trained crews and heavy equipment.
7. Accessory benefits in land improvement, stream clearance, flood control and waste water disposal are frequently significant.
8. Water management for mosquito control can be effectively coordinated with multiple use of wetlands for agriculture, wildlife propagation and water storage.

Logically, with complete and proper water management, the mosquito problem would be eliminated. However, we in New Jersey are quick to admit that our management of water is not always complete or proper and it is necessary to use insecticides which are expedient in alleviating the mosquito nuisance temporarily. Recognizing this, however, we believe that on a long term basis in areas where there is rainfall in excess of need, intelligent management of water is the only procedure that attacks the mosquito on a permanent basis and at the same time does not have serious side effects.

PRIMARY EMPHASIS ON LARVICIDES

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I can believe only that the reason I was assigned the responsibility of discussing the philosophy of larvicides, or as the program states "Primary Emphasis on Larvicides," is because I am a Californian who began his career in the field of mosquito control shortly after the introduction of an insecticide known as D.D.T. At first I thought this topic would present no difficulties. I merely would present dosage rates used, gallons applied, acres covered, materials used, equipment involved and results obtained in California. Simple enough? Yes! But as I began to develop the information, I began to have nagging doubts. Why larvicides? Why not biological control or source reduction or water management? In attempting to answer my own questions, I found that I had to go back to the actual beginning of mosquito control in the United States to better understand my subject matter.

From the literature, it generally can be determined that oil was the first material used to control mosquito larvae, and this occurred sometime before the 1800's. Dr. L. O. Howard published a pamphlet in 1900 entitled "Notes of the Mosquitoes of the United States: Giving Some Account of Their Structure and Biology with Remarks on Remedies," in which he stated that in 1867, as a boy of 10 years, he had used kerosene to kill mosquito larvae in a horse trough. Seventeen years later, Dr. Howard demonstrated the value of kerosene as a practical, large-scale remedy for mosquitoes.

By 1900, several communities were using oil as a mosquito larvicide. It was also in 1900 that John B. Smith, and a few years later T. J. Headlee, began to perfect control methods against salt marsh mosquitoes in the State of New Jersey. It is interesting to note that while Howard, Ross, Celli, Casagrandi and others were publishing their remedies for the control of mosquitoes using larviciding material, Dr. Robert H. Lamborn had published a book entitled "Dragonflies vs. Mosquitoes: The Lamborn Prize Essays." Apparently, Lamborn believed that if dragonflies could be domesticated, they could be used to control mosquitoes. Certainly, to Dr. Lamborn, a definite and obvious biological control method.

Dr. Howard, however, had different thoughts, for he stated: ". . . the whole subject of the natural enemies of the mosquito is of little practical importance." (L. O. Howard, 1900). This attitude probably set the stage for the years of larvicidal research which have continued to this day. In my opinion, Dr. Howard's attitude was not without justification. Little was known about the biology of mosquitoes, and less was known about their natural enemies. Words such as ecosystem, habitat modification, source reduction, adulticide, and water management were still to be born. Drainage of ponded waters was acknowledged to be most effective in controlling mosquitoes, but at the same time was dismissed as being somewhat costly. Furthermore, once the practicability of controlling mosquitoes had been demonstrated, every community plagued by mosquitoes immediately wanted to initiate control remedies. Consequently, the most obvious and direct approach was the use of oil or kerosene as a larvicide.

Have conditions changed from the early demonstrations of the practicability of mosquito control some 68 or 69 years ago with programs presently in effect? In California, certainly there is no reason to believe they have. Our programs still utilize the same directness of approach that characterized the programs of 1900. There are subtle differences that I believe are worthy of mention.

Today, the mosquito control technologist quite properly makes an evaluative study of the problem area in terms of its environmental and biological aspects or relationships. Then he attempts to select the most effective and economical control technique available within the framework of his organization, keeping in mind that the goal of all mosquito control programs is to reduce the mosquitoes in a geographical area to the lowest possible number.

Let us examine briefly the control efforts in California for the year 1964. Four insecticidal chemicals were used—and in huge quantities. For instance, approximately 108,000 pounds of parathion, 153,000 pounds of malathion, 16,000 pounds of Baytex and (strangely enough) almost 8,000 pounds of D.D.T. were consumed in the fight against mosquitoes. How were these materials applied? Primarily as larvicides. Twenty-two out of fifty-eight districts use aircraft in their operations, and they reported over 1,206,000 acres covered with larvicides.

I believe these figures clearly indicate that chemical or larvicidal control is still basic to California's efforts to control mosquitoes. Also I believe we will continue to attack mosquitoes with chemical applications, but not in such a direct manner. There is considerable evidence before us indicating that future control techniques will be far less direct. Habitat modification by chemical means (herbicides) is already a part of operational control techniques. It is indicated that chemical sterilants may soon be incorporated into operational programs. If so, then we have become involved in population control (I wonder if the mosquitoes will picket us). Most recently, the newer and more active surfactants have shown promise as a combined larvicide–pupicide.

Thus, I believe that the application of larvicide, when properly supported by entomological data, will continue to be an important and necessary technique in vector control programs. I know one thing: the doubts I had when I began to write this paper have been answered by the realization that time is relative to things and places. We can progress only as far and as fast as time will permit. Dr. Howard's conclusions were relative to his time, just as we are bound by the limitations of our knowledge today. It would be interesting to present a similar paper on the subject of larvicides ten or twenty years from now to see how much of the material I have presented today is still pertinent.

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POTENTIAL FOR NATURALISTIC CONTROL OF MOSQUITOES

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A most celebrated means of naturalistic control of mosquitoes is by the use of fish, and especially mosquito fish of the *Gambusia affinis* species complex. In the recent (1966) revision of J. B. Gerberich's 1946 annotated bibliography of papers relating to the control of mosquitoes with fish prepared by Dr. Gerberich and Dr. Marshall Laird of the World Health Organization, 686 references are given. Of these, 279 (41%) deal largely or exclusively with *Gambusia*. The closest runner-up, concerning only 8.6% of the literature, is the southeast Asian *Panchax (=Haplocheilus=Aplocheilus)* group. At 6.5%, the common guppy, *Lebistes reticulatus*, from Central America comes next, and after that few of the remaining 200 to 300 species occupy more than 2%.

Gambusia has become almost synonymous with the biological control of mosquitoes throughout the world; biological control being but a specialization of naturalistic control involving the utilization by man of natural enemies to reduce the numbers of a pest species. As a matter of fact, ecologist Frank Wilson has recently described *Gambusia* in "The Genetics of Colonizing Species" (1965) as the most widely disseminated of any species used for biological control. *Gambusia* has been moved to and established in almost every part of the world where it will survive since its first introduction from Texas to Hawaii in 1905.

Gambusia has not always lived up to its mosquito control expectations, however, and in a number of reported instances, it even has been described as detrimental to indigenous larvivore populations. Some of the habitats in which *Gambusia* has failed to give adequate mosquito control are those which are too cold, too plant-infested, polluted, lacking in protection from their own natural enemies, or simply too extensive or temporary for the fish to achieve mosquito controlling densities.

In short, *Gambusia* introductions into these situations were usually ill conceived, without taking into account either the ecological requirements of the fish or the conditions which the environment had to offer. Such mismatches of fish with situation have at times tarnished the otherwise excellent reputation of *Gambusia* as the number 1 naturalistic control of mosquitoes; but from the immediate and practical standpoint, number 1 it remains.

Although many mosquito abatement districts maintain stocks of *Gambusia*, distribute them where they see fit, and publicize their free availability to the general public, I think that we sometimes overlook the greater potential for these and other fish. This is partially due in recent years to the dramatic effectiveness, easy availability and convenience of modern insecticides. Another factor may be that where fish are effectively controlling mosquitoes, we tend to take the absence of mosquitoes for granted and thus it does not occur to us to transfer the fish to other situations where they might be useful. Two recent events have led me to this assumption. One is the document by Gerberich and Laird which I previously mentioned. In this it is pointed out that of the 686 references listed, 74% were published bteween 1900 and 1940. After the advent of DDT, references to mosquito control by fish became fewer, and only 6% were published in the decade prior to 1960. Now, with increasing costs of repeated insecticide application, resistance problems and residues, recent literature indicates that fish are returning to popularity.

The second factor that influences my thinking on this matter of taking local fish for granted is the response which I received to a recent article in TIME magazine (October 14, 1966) concerning my work with annual cyprinodontid fishes. Although the article was prompted by the unique feature of these fishes being able to withstand drought in the egg stage, much like *Aedes* mosquitoes, it was surprising to me the number of persons who read the article and were impressed simply by the fact that here was a fish that eats mosquitoes. These persons evidently were unaware that they probably have fish that are equally good for this purpose in their own local areas. What is more noteworthy is that the majority of these persons writing were with mosquito abatement districts, health departments, universities, and other professional agencies.

The annual fishes which I have mentioned involve several species native to South America and Africa, where they have been reported by various authors as being effective mosquito control agents in seasonally flooded or intermittent environments. These fish are remarkable in (1) their adaptation to temporary environments, (2) their rapid growth to sexual maturity within 4 to 5 weeks, and (3) their daily egg production thereafter.

Annual fishes are undisputedly larvivorous, but that they are responsible for the absence of mosquito breeding in the areas where they are active remains to be scientifically confirmed. For the present, however, these fish constitute an interesting potential for mosquito control in selected *Aedes* and *Anopheles* habitats which will permit their establishment. Except that there are a few species of annual fishes which tolerate near freezing temperatures for considerable periods, the future of these fish in mosquito control lies mostly in the tropics and subtropics, and then only in regions characterized by alternate seasons of rain and drought.

Since some of the most productive mosquito sources concern temporary waters where other fish cannot be established on a permanent basis, annual fishes currently are creating as much excitement as did *Gambusia affinis* in the 1920's and 1930's. To avoid the misapplication of these fish as much as possible, and thus to spare them the defamation often suffered by *Gambusia*, we are cooperating very closely with the World Health Organization in the consignment of these fish to other investigators. The intent here is that sound ecological considerations be given to the establishment of annual fishes wherever possible.

Another fish that seems long to have been overlooked, but which now is receiving renewed attention for mosquito control, is the guppy, *Lebistes reticulatus*, from Central America. Many attempts, most seemingly unsuccessful, were made in the early part of this century to establish *Lebistes* in southeast Asia. Recently, however, Sasa *et al.* (1964)[1] and Johnson and Soong (1963) have discovered thriving colonies of guppies in that region in what are said to be some of the most polluted waters imaginable. Subsequently, Sasa *(loc. cit.)* reported what appears to be a cold, hardy strain of *Lebistes reticulatus* in Japan. With these discoveries, we can see considerable potential for the naturalistic control of mosquitoes in situations previously thought to be too foul for this possibility.

Another foreseeable application of *Lebistes* is in temporary habitats that are unsuited to the establishment of annual fishes.

In warmer regions, impermeable reservoirs could be strategically placed in natural sumps of seasonally flooded areas to harbor fish during drought; in colder regions, the fish would have to be replaced seasonally, as is now sometimes done with *Gambusia*. *Lebistes* has certain advantages over *Gambusia*, however. One is that, as noted by Rebrin (1938), *Lebistes* has more closely spaced broods than does *Gambusia*. Although Rebrin reports work by Sokolov in which it is claimed that the overall fecundity for *Lebistes* and *Gambusia* is about equal, our own trials with these fish this past season indicate that *Lebistes* reaches phenomenally higher populations than does *Gambusia* in the same period of time. Moreover, smaller fish predominate in the *Lebistes* population, which allows this species to more effectively seek mosquito larvae among grassy vegetation. Our *Lebistes* populations were at a peak in July and August, and fish survived out-of-doors from April 15 through December 22.

Of advantage to us in some environments is that *Lebistes* is destroyed by cold weather. This prevents escaped individuals from surviving and reproducing in permanent water sheds where they might not be wanted.

A great advantage of both *Gambusia* and *Lebistes* is that these are of practical application in the frequently proposed practice of integrated control. Studies by several workers (Ferguson *et al.* 1966; Mulla, 1966; Patterson and Von Windeguth, 1964; Sasa *et al.* 1964) show that both of these fish species have considerable tolerance to most of the currently used larvicides at their respective rates of recommendation. Therefore, these chemicals can safely be used to control early mosquito broods and then discontinued as fish multiply and become effective.

The present potential for the use of fish in mosquito control is as great or greater than ever. Naturalistic control of mosquitoes by fish can now not only be abetted by the judicious use of pesticides, but also by modern herbicides and better water management practices, which are themselves a form of naturalistic control.

An excellent discussion on the forms of aquatic vegetation that can be useful in mosquito control is given by Matheson (1930) concerning his own work and observations by others on insectivorous bladderworts, surface covering species of *Lemna* and *Wollfia*, and submerged vegetation, including species of *Chara* and *Elodaea*. Most of Matheson's work concerned the latter two genera, especially *Chara*, which he found to

[1]Not considered formal publication.

inhibit both oviposition and larval development of several species of mosquito. His laboratory aquarium results with *Chara* are most convincing, although he is the first to point out the widely conflicting literature on the value of *Chara* as a mosquito control. Also, he arrives at a tenuous conclusion for the success of his own studies. Nevertheless, some of his speculations, made more credible by supporting investigations, are worthy of account. One hypothesis is that excessive oxygen given off by the plants may too rapidly oxidize organic wastes otherwise available as food for mosquito. larvae. This does not, of course, help to explain the oviposition deterrent. Concerning oviposition, Matheson found that *Culex* would never lay eggs on water where *Chara* was growing vigorously, but only where *Chara* had begun to decay. As *Chara* decay advanced, oviposition increased. In field tubs, excessive *Culex* oviposition took place in tubs lacking *Chara*, while in adjacent tubs with *Chara*, no oviposition occurred.

Next to fish, aquatic plants, where they are applicable, probably hold the most immediate practical potential for naturalistic mosquito control. However, even as Matheson described the basic problem to be in 1930, we still know too little about the fundamental physico-chemical factors of water itself, let alone the requirements of the plants and animals living in it.

Natural enemies of mosquito larvae are legion, representing nearly every freshwater phylum and order, as is evident from the annotated bibliography of pathogens, parasites, and predators of medically important arthropods prepared by Jenkins (1964). Although several of these references are to formal investigations, many more concern merely casual observations of natural enemy attacks on mosquitoes in nature. In any case, it is extremely difficult at best to ascertain the individual and variously combined effects of these organisms on mosquito populations. Furthermore, large-scale culture and management methods are much less developed for most of these organisms than for fish and plants. For these reasons, I hesitate to speculate on the potential for mosquito control by these organisms beyond that which naturally occurs and which we take for granted. Our best bet is simply to recognize these control agents and protect them whenever we can.

By way of adding documentation to the worth of at least two predators, I would like to mention briefly our last season's results with the backswimmer, *Notonecta unifasciata*, and the dragonfly naiad, *Bellonia saturata*. In tests using 100-gallon field tubs, to which egg rafts of *Culex peus* were added three times a week, totaling 10 egg rafts per week, adult mosquito emergence was nearly 100% prevented by as few as 10 notonectids and 95% prevented by somewhat larger numbers of dragonfly naiads. More than 12,000 mosquitoes emerged from the check over the 3-month period of the investigation.

Of the many novel and imaginative mosquito control approaches currently being investigated by various workers, which include sound attraction, pheromones, cytoplasmic incompatability, and sterile male release, most of these are in such early pioneering stages that their potential cannot be realistically predicted.

One fast upcoming approach to the naturalistic control of mosquitoes that does have sufficient precedent in the control of other animal populations is the use of disease. Insect pathology has only recently achieved disciplinary status, but many microorganisms have been known to infect mosquitoes and sometimes cause destructive epizootics among their populations for a considerable period of time. These microorganisms include *Coelomomyces* fungi, bacteria, microsporidian protozoa, and viruses; in short, the same general germ groups as affect human beings, except that some germs are as specific to mosquitoes as others are to humans. Some insect pathogens, such as *Bacillus thuringiensis* on lepidopterous larvae and milky disease bacteria on the Japanese bettle grub, have already proven to be economically useful and the likelihood seems good that pathogens will be discovered that will be just as manageable against mosquito larvae. Several of the *Coelomomyces* and microsporidia already discovered appear to be very promising, but too little is known of their life cycle, culture, and requirements for infection. When we know as much about the diseases of insects as we do about the infectious diseases of man, their potential for mosquito control should be as good as that of human diseases for biological warfare. Much more *useful*, we hope.

An interesting sidelight of mosquito pathology is the prospect for tailor-made super pathogens. This could be accomplished by the laboratory extraction of DNA from certain organisms and recombining it with that of similar organisms to manufacture organisms with the best qualities of both. The fundamentals of this work have already been accomplished by Dr. Eldon Reeves, of our own department, with forms of *Bacillus thuringiensis*.

Another microbial approach to mosquito control, and one that may yet prove best of all, is that suggested by R. Senior White in 1929, pertaining to the influence of microorganisms on water quality. Like Matheson's observations that mosquitoes failed to oviposit or develop in waters harboring certain higher aquatic plants, Senior White discovered that nitrifying bacteria at times have the same effect. He attributed *Anopheles* breeding inhibition to the nitrogen cycle in water and, more specifically, to the ammonia-nitrate ratio brought about by the regulative action of bacteriophages on *Nitrosomonas* and *Nitrobacter*.

Whether or not Matheson and Senior White were on the right track, one thing, as they both point out, has long been obvious to mosquito workers everywhere—that fact is the frequent absence of mosquito larvae, for no apparent reason, in waters seemingly suited to their development. As Watson (1921), according to Senior White *(loc. cit.)*, suggested: there is apparently "something in the quality of the water" which could be made use of for biological control. That something is evidently yet to be found, but who is looking for it? This is one obvious area of research that should have considerably more attention.

The potential for naturalistic control is always present. Its realization is only what we make of it. Its success is a matter of faith and understanding—faith in its value, and understanding where it already exists so as not to destroy it, understanding what its limitations are, and knowing what the materials are to implement it.

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TRUSTEES-COMMISSIONERS SESSION

CONCURRENT

MONDAY, FEBRUARY 6, 1:30 P.M.

JAMES W. BRISTOW, *Presiding*

TRUSTEES, COMMISSIONERS AND MOSQUITO CONTROL

DON M. REES
Salt Lake City Mosquito Abatement District
Salt Lake City, Utah

As announced, the subject I shall discuss is "Trustees, Commissioners and Mosquito Control." I might have more logically entitled it "Mosquitoes, Commissioners and Trustees," thus giving priority to the mosquitoes, as they seem to endure longer than the trustees or commissioners in a mosquito control district. Furthermore, mosquitoes seem to have a way of exerting a more direct and responsive influence on the citizens living in the district than do the members of mosquito control boards.

I am a trustee but I never have understood why some of us are called trustees and others are called commissioners when we both have as an objective the destruction of mosquitoes. For an answer to this question I called on Mr. Webster and found that a trustee is "a person holding the effects of another" and it further states a trustee is one to be trusted. Now a commissioner, according to Mr. Webster, is "one who has received a commission to perform a service." It did not mention anything about a commissioner being trusted. That is one difference between a trustee and a commissioner, and another difference, according to the definition, is the manner in which they are supposed to operate. A trustee, you will note, is to "hold" the property of others and commissioners are to "perform," that is, to use the property of others.

Accordingly, I know some trustees and commissioners who should exchange titles, judging from their holding and spending inclinations.

I was manager of a mosquito abatement district for eight years and during that time there was one trustee on the board who knew what a trustee is supposed to do because at each meeting of the board he determined the success of the monthly operation according to the amount of the unencumbered bank balance and not by the effectiveness of the mosquito abatement program. Perhaps a combined balanced board of commissioners and trustees would be most effective for operation and most destructive for mosquitoes.

Now we have determined why we are called trustees and commissioners, perhaps we should explore what, as board members, we are supposed to do. In New Jersey they have very high standards as they have established 'The New Jersey Mosquito Extermination Association." Apparently they expect the commissioners in New Jersey to exterminate the mosquitoes. The mosquitoes, I understand, are very much opposed to this and plan to fight to the bitter end which, at present I am told, is not yet in sight.

In Florida they have an "Anti-mosquito Association." From this title the commissioners in Florida are only required to declare they are anti-mosquito. This is a great relief for the mosquitoes and the relationship between the mosquitoes and commissioners is much more friendly in Florida than it is in New Jersey.

In California they have a "Mosquito Control Association," which, you must agree, is quite presumptuous and makes it extremely difficult for the trustees to fulfill their obligations. Who has ever heard of anyone really controlling anything, particularly mosquitoes? All married trustees and commissioners are aware that control is a word that has little meaning outside of a dictionary.

In Illinois and Utah the demands on the trustees are modest and can be more readily complied with as we have in these states "Mosquito Abatement Associations." The extent of mosquito abatement in these states apparently is to be determined by the boards of trustees of each district. For the trustees, this is a much more reasonable approach, but the mosquitoes must be aware that it is only an abatement program as they seem to be more bold and disrespectful to trustees in these states than they are in New Jersey and California.

In a more serious vein, it would be presumptuous on my part to tell you how you can best serve as a commissioner or trustee in your respective districts. Many of you have been serving in this capacity for a long time and you are doing a marvelous job judging from the results you have obtained in the control of mosquitoes in your districts. There are, however, others here today who have only recently been appointed as commissioners or trustees and therefore have only an introduction to the intricate operations of mosquito control. With the forebearance of those who are well informed and, I hope, with the support of all, I will try to outline, as I understand them, some of the duties and responsibilities of trustees and commissioners in a mosquito control district.

First, what is a commissioner or trustee of a mosquito control district expected to accomplish? The answer is obvious. He is expected to assist to the best of his ability in reducing the mosquito population in the district. In doing this, he serves on a commission or board which is established by law for this purpose. Some of these organizations may also, by law, include the control of flies, gnats and other noxious insects, but as stated in the title, I will restrict the scope of this presentation to mosquitoes.

The membership, organization, function, and procedure under which these boards and commissions operate are generally quite clearly defined in the law by which they are established. As a board member you are obligated to become well informed on the legal rules and regulations under which you must function. Then it is your duty and responsibility to be sure that the board and all operations in the district are conducted legally. If there is a doubt concerning the interpretation of the law, obtain legal counsel and preserve the opinion received in writing. If the law is inadequate, change it until it meets essential requirements to operate an effective mosquito control program. It is extremely important to operate in conformity with existing law, not that mosquitoes care whether your operations are legal or not, but it is essential for your own protection and that of the district in which you serve as a directing officer.

A board member should also become well informed on the basic principles of mosquito control. He must then apply this information in determining how mosquitoes can most effectively be controlled in the district, and how much it will cost to do a job that is acceptable to the public receiving the benefits and paying the bill for this service.

I emphasize, the program, to be successful, must reduce the mosquito population in a district to a level that will be acceptable to the public. That level is not the same in all districts, or the same at all times in the same district, as the number of mosquitoes the public will tolerate in a specific district is quite variable when compared with other districts and is determined by many factors. Some of these factors are: (1) the abundance of mosquitoes present in the district before the control program was applied; (2) the species of mosquitoes present, their relative abundance, their feeding habits and the annoyance they create; (3) their potential as vectors of the causative organisms of disease; and (4) the ability of those living in the district to fund the program. Mosquito abatement may mean a reduction of the mosquito population anywhere from a fraction of 1% to 100% but the cost of attaining 100% control, while possible, may be impractical, as the cost of such a program in most districts is not justifiable. This is based on the principle of diminishing returns and in a mosquito abatement program the destruction of the last few mosquitoes to attain 100% is the most difficult and costly part of the program and the benefits received usually do not justify the high expenditures necessary to attain such a goal.

The commissioners or trustees of a mosquito control district should determine the approximate number of the different species of mosquitoes that can be present in the district without creating a conspicuous annoyance or an eminent disease hazard. Funds to conduct such a program should then be obtained and expended in a manner to most effectively maintain this established mosquito population tolerance level.

The information necessary to plan and execute such a program is obtained largely from experience which includes the experience of others who have successfully conducted mosquito abatement programs in similar situations. Information is also gained from practical experience obtained from the response of the public to the different species of mosquitoes in the district, and their numbers as they fluctuate during a season and from year to year.

Profiting by the experience of others is possible in mosquito control work today as considerable information is available on how to measure mosquito populations and the general response of the public to the increase of different species above the generally accepted numbers.

Information is also available on methods and techniques that have been used successfully in mosquito control work in other districts and in practically all kinds of situations. Some of these methods may be suitable for use in your own district, others with some modification may become useful.

This information has not always been available because it did not exist when mosquito control work began in New Jersey, California, and other states that pioneered mosquito control programs. As a result many expensive mistakes were made in most of these earlier programs. Unfortunately in some districts today, particularly in some of the newly organized districts, mosquito control methods are used that are ineffectual or only partially effective when compared with other known methods that are being applied successfully in other similar areas. The responsibility rests directly upon the governing board to prevent these needless and costly mistakes from happening in any district today and it is a disgrace to have them perpetuated year after year as they are in some districts. These boards today have considerable information available on how successful mosquito abatement districts are operated and the results obtained. They should evaluate this information and compare this with the methods used and the results obtained in their own districts and then improve accordingly.

Concerning the governing board, it is essential that each member be genuinely interested in and deeply concerned with the development of the most effective mosquito control possible in his district. If a board member does not measure up to these standards, if he fails to regularly attend board meetings, replace him as soon as possible with someone who has these qualifications, as a disinterested or absentee board member not only fails to make a contribution but he is also taking the place of someone who could make a greater contribution to the success of the program.

If possible, it is desirable to have on the board members who represent different geographic areas within the district and who represent different segments of society such as the professions, business, and labor. All appointments should be made on the qualifications of the individual and not as the result of his political affiliation.

If I were restricted to making only one recommendation to all board members on how they could discharge their duties most efficiently as members of the governing body of a mosquito abatement district, I would not hesitate in making a choice. I would recommend that they act exactly as they would if they were shareholders in a large business enterprise and as board members of this business they would want it to function as efficiently and successfully as possible. Actually, mosquito control is a large business enterprise and you are all shareholders in this organization. In addition, you are representing all of the people living in the district and they, as shareholders in this organization, are depending on you to get the most out of every dollar they contribute to this program.

As a commissioner or trustee, you can only devote a small part of your time to mosquito control work; therefore, as in any successful business enterprise, one of the first things you should do is appoint a competent individual to manage the program. The degree of success of the program of any cooperative business enterprise is largely due to the competency of the man selected as manager. His title is of little importance; it may be manager, director, supervisor or some other title. His duties and qualifications are all important to the success of the program.

Let us consider some of the qualifications essential for a good manager. First, we all agree he must be a good administrator. There has been some discussion as to whether by training the manager should be an entomologist, ecologist, engineer, accountant, or trained in business administration.. It has been demonstrated that a successful manager can be trained in any or none of these specialized fields. It is an advantage if he can provide expert services in entomology, engineering, or some other specialized field where such services are required in mosquito control work, but this, in larger districts, is not essential as such services can be obtained from specialists in these fields.

It is essential that a manager thoroughly understands the basic principles of mosquito control and be able to determine the most effective methods for use and proper application of the same in the district in which he is manager. Such a manager will be aware that there is always a need for improvement and he will obtain the services of trained personnel in the fields where such services are essential for improving the program. A manager should also be outstanding in his ability to explain and sell mosquito control to others and in so doing obtain their support. He should be able to obtain the cooperation of and substantial active support from federal and local government agencies, civic and social organizations, industry, and property owners in the district. By cooperation and support I do not mean lip service, I mean active participation in the program. It has been demonstrated in many districts that locally there is a tremendous source of available assistance for mosquito control in all districts. The manager is delinquent in his duties if he fails to obtain this available support for strengthening the program. At times the manager can obtain this support more readily by working through an appropriate board member.

As in any business, the manager serves under the direction of the board as a whole and is accountable to it. In general, the manager is expected to prepare organizational and operational plans and budget estimates which he should submit to the board for consideration. When approved, the manager is obligated to put these plans into operation within the budget provided. A manager should receive the full support and backing of the board in discharging these duties and should not be harassed by individual board members. He should be able to call upon individual board members to discuss and obtain advice upon problems on which they are especially qualified, but decisions concerning changes in policy or plans in major operations are matters for the board to decide.

If, after careful consideration, the majority of the board agrees that the manager is not measuring up to the requirements expected of the manager of the district, he should be replaced. This decision, in most instances, cannot be based upon his performance during one season as conditions in some years make it almost impossible to conduct effective mosquito control.

There is another aspect of this problem which must be kept in mind, that is, managers of districts are sometimes retained by governing boards when they do not measure up to conducting the most effective mosquito control program possible in a district. A manager who is a good salesman may sell himself to the board so completely that the board is unable to impartially evaluate his performance. A failure of the board to properly evaluate a manager may occur for several reasons, such as his years of service, from personal friendship, or simply to avoid an unpleasant duty. The assessment and evaluation of the services of the manager should be made each year as a matter of business, possibly when contracts, salaries and wage scales are considered and the judgment should be based on the results he has obtained in mosquito control in the district.

Governing board members of most mosquito abatement districts have reason to be proud of the success they have attained in mosquito control in their districts. With success, most of us obtain considerable satisfaction in telling others how well the program is going in our district. This is to be expected when we are interested in our work and take pride in our accomplishments, but we should also seek to profit by the success of others who are engaged in this work.

In summary, I reiterate: The governing board of a pest mosquito control organization is expected to reduce the mosquito population within the boundaries of the district to a level where the mosquitoes do not create a conspicuous nuisance or eminent disease vector hazard. This approximate mosquito population level is not the same for all districts but this level can and should be established for each district.

In order for the governing board to accomplish this most effectively and economically, each board member must conduct himself and make his decisions as he would as a member of the governing board of any successful business enterprise.

To be competent to make important decisions expected of him a board member should become well informed on the following: (1) the law governing the organization of the district and the procurement and expenditure of funds, and (2) the basic principles used in mosquito control operations. This information is essential to effectively direct the control program and provide the benefits to which the employees are entitled and to obtain the necessary support and protection for the board members.

To manage and daily direct the program, the board should employ the most competent person available for this position. The board should depend on the manager to operate a successful program. They should support him in this office as long as he serves in this capacity. If the manager fails to measure up to the expectations of the board, after adequate opportunity to produce, he should be replaced, because the success or failure of a mosquito control program is largely dependent upon the ability of the manager.

Effective mosquito control is a reality. This has been demonstrated in many mosquito control districts throughout the country. If you are not obtaining satisfactory results in your district, examine your current methods very carefully, as satisfactory control is possible.

If you think you are operating a sucessful mosquito control program in your district, do not be satisfied to rest on your laurels, take another critical look at your program; there is always room for improvement.

PANEL: CURRENT TRENDS OF UNIONIZATION AND CIVIL SERVICE

JAMES N. LESPARRE, *Moderator*

WILBERT AALTO

Consolidated Mosquito Abatement District

Reedley, Calif.

In behalf of the great San Joaquin Valley I welcome all of you from throughout the United States to visit the richest agricultural district in the world at some future time. I know San Francisco will be a great host to you during your stay here.

A December 7 Pearl Harbor-type attack hit Consolidated Mosquito Abatement District on August 16, 1965 with this letter: (Dated Aug. 5, 1965)

Board of Directors
Consolidated Mosquito District
2425 Floral Avenue
Selma, California

Attention: Mr. L. E. Gustafson, Secretary

Gentlemen:

You are hereby notified that this Local Union has been authorized by a majority of the employees of the Consolidated Mosquito District to represent them on all matters relating to employment conditions and employer-employee relations, including, but not limited to, wages, hours and other terms and conditions of employment.

We hereby request such recognition from the Directors.

If there is any question as to our claim of a majority status we will be happy to submit any such question to the determination and certification of the Conciliation Service of the Department of Industrial Relations of the State of California.

We will also appear before the Board at the next regular meeting, August 19, 1965, in Selma.

Looking forward to a mutually agreeable relationship in which the Directors, the Union, its membership, and the public can take pride, I remain,

Sincerely yours,
J. C. BATEN
Secretary & Business Manager

CC: Conciliation Service
Industrial Relations Department
State of California

A representative from the International Chemical Workers Union attended the August district meeting and read a copy of the August 5th letter to the Board. In that the request by the Union was new, a motion was made to hold the matter open until more information was available. The Manager was instructed to invite the Fresno County Counsel to the next regular Board meeting, September 20, 1965.

At the September 20th meeting the President recognized the visitors present and indicated comments were in order. Mr. Stewart, Business Representative, Local 97, I.C.W.U., stated that he would act as spokesman for his group. He opened his remarks with a reference to the Union's August 5th letter and elaborated on its contents. None of the other Union representatives wanted to speak at this time so the President asked County Counsel Wash to comment on the matter. Mr. Wash referred to sections of the Government Code pertinent to the matter and outlined his interpretation of the various provisions of the code. He emphasized that the Board must adhere to the requirements of the Code and advised full compliance with Section 3505 which reads:

"The governing body of a public agency, or such boards, commissions, administrative officers or other representatives as may be properly designated by law or by such governing body, shall meet and confer with representatives of employee organizations upon request, and shall consider as fully as it deems reasonable such presentations as are made by the employee organization on behalf of its members prior to arriving at a determination of policy or course of action."

To follow fully the advice of the County Counsel a motion was approved to authorize the Manager to represent the Board between the regular meetings on matters relating to District personnel. A followup on this was a meeting reported as follows:

MANAGER'S REPORT ON MEETING WITH DISTRICT EMPLOYEES' REPRESENTATIVE
September 23, 1965

As authorized by the Board of Trustees at the regular meeting September 20th, 1965, arrangements were made in a telephone conversation initiated by Mr. James E. Stewart, Business Representative, Local 97, International Chemical Workers Union, for a meeting at 10 a.m. September 23, 1965, in the district office in Selma. In the telephone conversation Mr. Stewart's suggestion that certain district employees be present at the Thursday meeting was not vetoed by the Manager; however, he did question the advisability of this procedure for the first meeting.

Mr. Stewart was prompt on the meeting day and as the business activity in the front office was quite noisy the laboratory was selected for the discussion. Gossip on current events filled the settling in period as records were organized and note-taking material prepared for use.

Preliminary discussions were directed to a review of the September 20th Board meeting. Mr. Stewart provided the names and affiliation of the people in his delegation at the Monday meeting. Notes taken by the Manager at the Board meeting were discussed in detail to be sure there was mutual agreement on the main points covered.

Stating that it was not customary to introduce these particulars at such an early stage of the proceedings, Mr. Stewart was agreeable to outlining the major items the employees he represented were concerned about. These were:

Salaries and wages

Medical and hospital insurance

Access to District job facilities by employee representatives

Bulletin boards in each District building for posting all material pertinent to employer-employee relations

A determination on allowable time for employee participation in developing proper employer-employee relations

The Manager indicated all District records were open to the public and that copies of any written record of meetings on the matter at hand would be available to Mr. Stewart. He offered to send a copy of a standard union contract for district review and suggested another meeting at an early date with certain district employees his Union was representing in attendance. This was quite agreeable to the Manager and the discussion was terminated with the understanding Mr. Stewart would arrange the tentative date and time for the next meeting.

This meeting was followed by almost weekly meetings before the October Board meeting. While these meetings were in progress a "Letter to the Editor" appeared in the Sanger (Calif.) Herald for October 14, 1965. It set the tone for many more public statements by the Union representatives.

LETTER TO EDITOR TAKES SWING
AT MOSQUITO ABATEMENT BRASS

Editor:

Government—and the expenditure of tax money—is the people's business. It should be public policy for governmental agencies to deal fairly and squarely with their employees.

When a governmental agency, and/or its appointed administrative officer, takes a position that can only be interpreted as consistently anti-labor, we think that the public should be alerted, and if necessary, take action at the polls when the occasion arises.

But—what if that agency smugly contends that once appointed they cannot be compelled to answer to anyone?

Suppose they contend that no one from the governor on down can "interfere" with their operation?

Should appointed officials, spending taxpayers' money, be above the law?

Should appointed officials be allowed to continue in office when they refuse to abide by the spirit and intent, if not the actual letter, of the government code applying to all state agencies?

If you think this is not happening right here in Fresno County—you have a surprise coming.

We direct your attention to the Consolidated Mosquito Abatement District. We intend to bring a number of facts to your attention concerning the Consolidated District and their method of operation. We are going to ask a number of questions—and you should be interested in the answers.

Until the board of directors—and the appointed manager—of the Consolidated Mosquito District demonstrate that they are willing to act within the framework of the government code and give their employees the consideration they have the moral and legal right to expect we intend to bring a continuing series of facts to your attention—and publicly ask a number of questions about their operations. We intend to see that the public—whose business all this really is—is fully informed.

(Signed)
James E. Stewart

There was a succession of statements and resolutions presented by the Union for Board action. These were referred to the County Counsel and handled as he indicated. At the December 20, 1965, meeting a motion was approved to have the President appoint a committee of two trustees and the manager to prepare a proper procedure for recognizing employees and/or their representatives. The resolution prepared by the committee and the County Counsel was adopted by the Board at the regular January meeting. Letters were received from the Union dated January 31, 1966, and March 17, 1966, requesting that they be recognized as provided in the resolution. In that neither request fulfilled the requirements of the resolution both were tabled.

A letter dated December 22, to the Board from the full time employees of the District, was read at the January meeting. These employees indicated they had formed their own group and had appointed a spokesman to meet with the Board on discussions relating to wages, working conditions and other pertinent problems. Just recently this group has formed an association of District employees with officers, dues and tentative bylaws.

Letters from the Union were sent to city councils, State Division of Industrial Safety, newspapers, Board of Supervisors, Grand Jury, Fair Employment Practice Commission and others. The contact with F.E.P.C. stimulated a complaint of employment discrimination. The cmplaint charged that an applicant for the District Chief Pilot's position had been passed over because of race. A hearing was set July 1, 1966, in Fresno. The Manager's report on this meeting was:

To: Board of Trustees
From: T. G. Raley, Manager

Subject: July 1, meeting on the James Wells complaint

As arranged by Mr. S. O. Connelly, Consultant, Fair Employment Practice Commission, the Manager met with Commissioner C. L. Dellums and Mr. Connelly Friday, July 1, 1966, at 2 p.m. in the state building, Fresno. In the June 17 letter verifying arrangements for the meeting it was indicated Commissioner Dellums is directing the investigation of Mr. James Wells' complaint of employment discrimination. Commissioner Dellums outlined the purpose of the meeting and indicated proceedings would be informal with questions permitted at any time.

After approximately one and one half hours of presenting pertinent material, review and discussion the

Commissioner asked Mr. Connelly if he was ready to make a recommendation. Mr. Connelly recommended that the District offer Mr. Wells the position of Chief Pilot and that he receive back pay from the time the position was first filled.

Commissioner Dellums expressed the opinion that Mr. Wells should be offered the position as he applied for in November 1965; however, it was his feeling the payment of back wages need not be pressed. He indicated Mr. Wells should be given thirty (30) days to consider the job offer.

The Manager requested adequate time to advise the District Board of Trustees of the recommendation. It was agreed that the response by the Board would be reported to Mr. Connelly as soon after the July 18 meeting as practical.

After the meeting Mr. Wash, Fresno County Counsel, was contacted. It was his opinion that the District should not follow the recommendation of the Fair Employment Practice Commission personnel.

At the July Board meeting a motion was approved to continue with the present method of hiring personnel. Included in the motion was a directive to the Manager to include in the minutes a statement on the circumstances related to the hiring of the Chief Pilot.

In August the publicity generated by the District's involvement with the Union initiated action by the Local Agency Formation Commission to study the boundaries of the Fresno County mosquito abatement districts. The matter has been discussed at several meetings of the Commission, in the press and at gatherings of city and county officials. The County Board of Supervisors have ordered the study but have failed to provide funds to conduct the necessary investigations. At this time efforts are being made by the Commission to obtain federal funds for this and a study of other special tax districts.

Perhaps the height, or depth, of the Union attack on the District came on the 22nd, 1966. Members of a delegation from the World Health Organization were handed a copy of the following by the Union representative as they arrived at the Fresno Mosquito Abatement District for a tour.

To Our Distinguished
Foreign Visitors:

Welcome to the United States and the State of California!

We are proud of our Country and our State. We hope that what you see and learn here will be interesting and constructive. We realize that we are not perfect; therefore we try constantly to improve those things which are good—and correct those things which are wrong.

It is unfortunate that, in most instances, while visiting another country on a conducted tour, you see and learn only those things which your official hosts want you to see. And perhaps you might feel that it would be ill-mannered to ask probing or pointed questions that might embarrass your hosts.

As taxpaying citizens of this country and state—as well as representatives of an effective segment of our society—we feel that we too are your hosts. We want you to see and learn all about our country—even if you learn something which might not be very flattering to some part of our government system.

We can say these things to you because the right to dissent—freedom of speech and freedom of the press—are at the top of the list of our most cherished possessions.

We have the constitutional right to publicly expose any wrong doings or malfeasance of any public official—whether he be elected or appointed. If the system whereby he attained office is wrong—we can also oppose that. We can exercise these rights without fear of reprisal as long as our charges are true.

You are going to visit the Consolidated Mosquito Abatement District. Don't allow the wool to be pulled over your eyes during this visit: Ask questions!

We contend that the structural organization, administration and operation of the Consolidated Mosquito Abatement District is a disgrace to good government. It should be a stench in the nostrils of every citizen who believes in good government. The attached statement and questions will give you some idea of why we make these charges.

Again—Welcome to our Country and our State! May you learn much that will be beneficial to your Country and your people.

Fraternally yours,
James E. Stewart
Representative

Copies of this same "letter" were distributed by hand in each city in the District, along with a three-page tirade starting off:

YOUR TAXES ARE GOING UP!
DON'T YOU LIKE IT?
WELL—THAT'S TOO BAD—JUST WHAT ARE YOU GOING TO DO ABOUT IT?

If you live in the CONSOLIDATED MOSQUITO ABATEMENT DISTRICT your taxes are going up whether you like it or not.

You didn't have an opportunity to vote against the increase.

You didn't elect the people who are raising the tax.

You have no control on how the money is going to be spent.

And it appears that you can't have the people removed from office who are responsible for the increase and the spending.

What are you going to do about it?

Even a lamb bleats and kicks when he is being sheared!

Here are a few things that you should know about the CONSOLIDATED MOSQUITO ABATEMENT DISTRICT:

From this "high" the matter more or less coasted until the present. No one from the Union has been at the last two Board meetings but things could change as seasonal help is hired again.

It has been a pleasure to spend this time with you and I sincerely hope you are spared a similar experience. Arrange your travel schedule to include Fresno in 1968. The California Mosquito Control Association will meet there in late January.

CIVIL SERVICE SYSTEM

LESTER R. BRUMBAUGH
San Joaquin Mosquito Abatement District
Stockton, Calif.

In these changing times, no organization, company, or governmental agency can afford to stand still in the employee relationship field. The constant change in public opinion, labor laws, economic trends, civil rights movements, increased activities of organized labor in public employees associations are some of the factors causing a constant change in the employees' working field. As conditions change, labor management policies must change to keep abreast of the times. Otherwise, the agency may be forced by pressure or other circumstances to make decisions without sufficient knowledge of probable consequences. Generally, under these circumstances, policy mistakes once made, as so many of us know, become extremely difficult to change. To avoid making mistakes we believe some type of formal written procedure should be developed in a calm atmosphere when dealing with employee problems. You might say that organized labor is not a problem to me, but in a review of government records, the growth of membership in organized labor and public employee associations is quite surprising. Don't wait until they knock at your door and panic you into making an unwise decision.

The purpose of this discussion today is not to convince you that any system of management-employee relationship is superior to another; instead, I will try to give you a few ideas that may be helpful in making your own appraisal of civil service. In dealing with personnel problems it appears that one of the best systems being used is the civil service system. It consists of placing employees on a merit basis for the purpose of obtaining the best qualified people available for service in the agency.

The question might be asked, "What is a civil service system?" It is simply a written procedure which provides equal opportunity within public service for all people in the area. Perhaps it might be better to describe the system as a set of rules and regulations which cover the procedures for hiring and firing, method of giving competitive examinations, holding hearings, procedures for handling employee grievances, job classifications, etc.

As far back as 1863, the federal government started using this system to replace the so-called "spoils system." Since that time the merit or civil service system has now become established in most states of the Union and in a great number of cities and counties of any size. Among the different states, cities and counties there is a wide variety in legal structure, scope of responsibility and methods of practicing the procedures used in a civil service system. For example, in the State of California, the legislative body establishes laws pertaining to the State civil service system and these laws may be found in the California government code. In the different cities and counties, the City Council or Board of Supervisors have the authority to establish civil service procedures by city or county ordinance. It is only natural to expect variations when you consider the number of states, cities and counties that we have throughout the nation. For mosquito abatement districts, the Board of Trustees is empowered, if they so wish, to establish rules and regulations pertaining to a civil service system. From all information available it appears that any mosquito control agency may establish rules and regulations regarding employee working conditions, and may call such rules and regulations a civil service system, if they so desire. Most states will supply rules and regulations, copies of examinations, job descriptions, methods of holding hearings, etc., upon request of any government agency.

Perhaps you are wondering what advantages and disadvantages there are in the use of a civil service system. The only disadvantage that I can name is the time and effort required to draft the rules and regulations, writing of job descriptions for the different job classifications of the agency, etc. Next, after such rules and regulations are made, the agency is required to follow them if they expect the employee to respect such a system. The advantages of this system are: provide equal opportunity for those entering the agency's employment, (if they meet the required qualifications); improve the working climate of the personnel; eliminate political pressure regarding hiring practices; and, prevent misunderstanding between employer and employee.

We certainly believe this system has many advantages over the "spoils system", where nepotism and political pressure can become established in a government agency if no safeguards are provided for management. Normally, without some type of written rules, the employer would be in a state of confusion when dealing with labor problems.

A NEW APPROACH TO PUBLIC RELATIONS

PAT COHEN AND ARTHUR L. CAVANAUGH
Coachella Valley Mosquito Abatement District
Thermal, Calif.

The Coachella Valley Mosquito Abatement District was organized in 1928 in an attempt to control the *Hippelates* eye gnat which had become a serious pest. Circumstantial evidence gathered in California, Georgia, Texas, and in other countries, by various scientists incriminated them as the vector of conjunctivitis, or pink-eye, a quite dangerous disease of the eyes of young children.

Although research has been carried on almost from the time the District was organized, about ten years ago the Board of Trustees of the District made a wise decision when they developed a working contract with the University of California at Riverside, Department of Entomology, to undertake research on this problem. The research started out rather modestly, but it has expanded to include the Department of Biological Control and the Department of Agronomy, with yearly grants totaling $22,000.00.

We have tried in various ways to get over the story of the work that is being done, not only in mosquito control, but the control and research in connection with the *Hippelates* eye gnat, which is such a pest in the Valley. We have had articles in newspapers, on the radio, television, and for several years a booth at the National Date Festival in Indio. But none of these seemed to get through to the public. We made attempts to take people on tours of the University at Riverside to see the work done there and the research in progress. But the Valley seems to be so over-organized — tremendous social pressure, sporting events, civic events — that people just could not seem to be able to get together to go at any specific time.

When we observed the popularity of the science fair which California is now promoting in the schools, organized by the various local school boards, for 7th grade through high school, to interest students in science projects, we conceived the idea of inviting the science teachers and some of the prominent citizens of the Valley to the District, but this did not develop as we felt it should. Then we decided to have a Science Seminar and free barbecue. We invited science teachers from all the Valley Schools—including Palm Springs, some private schools, and parochial schools — asking each teacher to bring two promising students. We invited some seven or eight of the professors from the University of California at Riverside to come down and give talks on their work. These talks are often illustrated with color slides; also science projects are set up along the walls of the auditorium —our garage, shined and cleaned for the occasion. The exhibits which are set up include "Instant fish", where the eggs are dropped into the water and fish hatch almost instantaneously! There are also various stages of the gnat's life and tests of mosquito larvae for resistance. The walls of the garage are lined with exhibits, set up to interest the students in our work and give them ideas for research projects of their own. We help many students in their projects with information and material.

Following a coffee break, 8:00 to 9:00 a.m., the talks are from 9:00 to 1:00 p.m., with a half-hour break about 11:00 a.m., at which time our equipment is demonstrated. At 1:00 p.m. comes the barbecue, prepared and served by our crew. At the barbecue, the professors are dispersed at the dozen or more tables among the children and it is most rewarding to hear the flow of questions and answers and the rapport that develops. The children flock around the doctors like bees around flowers. It has proven to be a fantastic idea. We have had many parents call and express their appreciation of the event and their interest in learning what is going on in the Valley. The children themselves sit the whole four hours in rapt attention, furiously taking notes — some of them as many as eight pages. One of the doctors remarked after the last seminar, "If we attract one or two of the large group to the field of science, it is well worth the effort involved".

A side product of the event is the immense pride and interest felt by the employees. The boys dig in with good will to prepare for the event and serve the barbecue with the skill of professionals. It seems to give them added pride in their work and a feeling of being involved in something worth while — rather than just holding a job!

We also have for distribution literature from the various chemical companies describing the importance of chemicals in the control of insects — not only with the mosquito abatement districts but with the farmers. Also available is literature of the history of mosquitoes in the State of California.

A newspaper reporter at the seminar remarked "The best way to spread news is to get to the children". This has proven quite true. Many parents have called us and said their children are really excited about the event, talking about the different doctors and the whole general program and how wonderful it is.

For our 1967 Science Seminar and barbecue, we shall extend invitations to the Trustees and Managers of other mosquito abatement districts.

TRUSTEES-COMMISSIONERS SESSION

CONCURRENT

TUESDAY, FEBRUARY 7, 8:00 A.M.

BREAKFAST MEETING

Frederick G. Deiler, *Presiding*

REPORT OF THE TRUSTEE CORPORATE BOARD C.M.C.A.

Fred DeBenedetti, *Chairman*

During the past year the Trustees developed a set of bylaws to serve as a guide for the Corporate Board. These bylaws are rather short, yet provide a reasonable plan to work by. Four meetings of the Trustee Corporate Board were held during the year. Some were not well attended. Each of the five geographical regions of the State has been asked to appoint a man to serve on this Board. Also included in the bylaws is a provision for an alternate in case the official representative cannot make a meeting.

The Trustee Corporate Board set up a statement of policy and objectives. We felt that at no time was it our job to run the CMCA. That is a job for the CMCA Board of Directors. We believed we could serve best in an advisory capacity, to try to function at the call and will of the Board of Directors. At the last regional meeting we recommended that the term of office of a member of the Trustee Corporate Board be limited to two years. We felt we should stay on long enough to know what we were doing, then go off and give somebody else a chance to learn.

It was moved from the floor and duly seconded that a two-year term be established, with appropriately staggered terms for the five members.

Jay Price, Trustee of Southeast MAD, offered a substitute motion that the two-year terms begin this year, staggered so that three members would be in one bracket and two in the other. Further, that the two-year limit applies to the Board member, not the alternate. The substitute motion was moved, seconded and passed.

In another action, the Trustee Corporate Board requested that the CMCA Board of Directors consider the employment of a full-time executive secretary. It also suggested that the AMCA consider the same proposal.

Jay Price: All of us know that there is a trend in today's government, from Florida to California, to do away with special districts, and to make larger and larger governments. But we know that big government is not always effective or economical government. As this governmental consolidation continues, one of two things may happen: the government may move in and say "we're going to take over your program, and you are out," or it may say "we will use you because you are the expert and you already have the organization."

Both California MCA and AMCA need somebody in control at the pillar, an Executive Secretary. We know we cannot get such this year, but we should start discussing the matter now, so that within several or a few years we will have a functioning office.

James W. Bristow: For the benefit of our visitors from out of state, let me review a little of the history of our Trustee Corporate Board. I attended my first meeting of the CMCA in Sacramento four years ago. At that time CMCA had on its Board of Directors one Trustee member. He was the only appointed or elected official serving in any capacity in the CMCA. The Trustee member at that time was Carl W. Muller, a trustee of the Turlock MAD. At the Sacramento meeting the trustees held a lengthy and at times controversial session. Above all, we trustees realized we needed to think about the many problems of CMCA. We started to take a part in the Association's affairs. Let me repeat what Fred DeBenedetti said—the Corporate Board is not set up to run the CMCA. The CMCA is basically a technical organization made up of managers, entomologists, and others in the profession. They are spending taxpayers' money to operate their organization. Certainly we, as the policy makers for this organization, should be behind them; we should help them, we should give them the support of our names .We should support them in their legislative aims, because we are the politicians, we are the men who have been appointed or elected to office.

This is the background which led us to organize the Trustee Corporate Board.

MIDMORNING MEETING

Christian A. Vieser, *Presiding*

PANEL: POSSIBLE CONSOLIDATION OF MOSQUITO CONTROL AGENCIES INTO HEALTH DEPARTMENTS

William Dryden, *Moderator*

Christian A. Vieser
Secretary, Jefferson County, Texas Mosquito Control District

On March 16, 1949, the Texas Legislature passed an act to enable the 254 counties of the state to have mosquito control. However, final approval limited the act to those counties that bordered the Gulf of Mexico —just 17 of them. Those were the only ones which could establish a mosquito control district and set a tax rate, up to 5¢ per $100 valuation. The act further provided for an advisory commission to advise the county commissioners. The mosquito control district commissioners are a part of county government, to recommend to the county what they believe to be the best policies, the best type of district, the amount of money needed, etc. The county commissioners may approve or disapprove these recommendations.

The advisory commission reviews the important position classifications within the district and passes on them. While the commission hires the district director, it always gives the director the power to hire the hourly people.

In 1955 there was a legislative amendment which provided that any two counties or more could amalgamate and form a bigger mosquito control district. This seemed fine when the amendment was approved, but it did not work. To have been politically acceptable, the two counties would have had to have the same valuation, the same size, the same problems, etc. No such situations existed.

In 1961 we asked the Legislature to make two changes: we needed more money, and we wished to permit mosquito control in all of Texas. We were beginning to recognize encephalitis in the inland counties. The Legislature accepted these changes, but they did ask "you now have up to a 5¢ tax, why do you want to go up to 25¢?" We explained that where the valuation was high, the tax rate could be low, but where the valuation was low, a higher tax rate was needed in order to operate a district.

Another problem, however, still had to be solved. In Texas a mosquito control district is still part of the county government. There is a law in Texas that a county government cannot tax its local citizenry more than 80¢ per $100 valuation for the general fund to operate the county. Mosquito control money must come from this general fund. If a district is getting 5¢, it may be getting as much as the county can afford to give. But if the district were to take 25¢ of the 80¢, the county might have to close much of its activity, which it probably would not do.

Therefore, we now have in our present session of Legislature a new provision—to take the mosquito control districts out of the county government's hands and create a separate governmental agency—like a drainage district or a college district. Such a district would have its own taxing powers, and would not have to go through the county government. It would, of course, use the county tax roles. If this law passes the Legislature, we will need a constitutional amendment, and the voters of Texas will have to vote on it next November. We hope these provisions will be approved.

Mark J. Hanna
Trustee, Alameda County, California Mosquito Abatement District

The suggestion that mosquito abatement districts be consolidated into health departments stems from three beliefs: 1) There would be more mileage from our tax dollars, 2) we could utilize managerial, professional and perhaps supervisorial assistance more efficiently, 3) we could reduce the total manpower of the Boards of Trustees.

As Trustees, we are obligated to do a commendable job of controlling and, if possible, of eradicating mosquitoes. We should endeavor to abate mosquitoes in an efficient way. Neither efficiency nor economy, however, is an objective in itself, but the two become merely forms of measurement. The purpose of being efficient or economical is to make the conserved resources available for expenditure or use on other things which we either need or desire.

We here today are among the leaders of our society, and it is our primary obligation to advance the civilization in which we live. There are many frontiers in the United States and the world today which demand the very best that we can produce, in research, in management, in organization. If these areas are to be explored, analyzed, and exploited, it will have to be accomplished with the brainpower that is available.

The initial years of a mosquito abatement district are in effect a pioneering, frontier effort which may require the very best efforts of trustees, management and labor to bring the problems under control. Beyond that point in time, however, the requirements in exploration, study, organization, innovation and effort decrease. The same amount of brains is no longer needed. Those brains could be freed for other frontiers if a mosquito abatement district were then transferred as a going organization to a larger agency. The men are trained, the operations are standardized, the decisions are no longer difficult, and the variations from the norm are no longer surprising. The need for professional evaluation and diagnosis is less, and can be accomplished by entomologists, managers and commissioners with larger overall areas of responsibility.

In California the annual mosquito control bill amounts to $7,000,000. This should be utilized so that the public gets its money's worth. Property taxes in California are very much in focus at this time. The taxpayer is largely a captive, with little real choice in the matter, and so it devolves onto the leaders of our society to see that the taxpayer does receive the good life. We as part of those leaders think we know what is best for our people. We make the rules, we take their money, and we spend it on them.

In the nine counties surrounding the Bay Area there are over 900 governments each with taxing power. Ninety-one of these are municipalities, while over 800 are essentially single purpose districts with the power to tax. Our form of civilization has come a long way, but we still have a long way to go. California State law specifies that there shall be a minimum of five trustees in a mosquito abatement district. But in our District there are 12. One represents the county, and 11 represent the cities within the District. In July we will add another—that will be 13. This appears particularly overbalanced when it is realized that we have only 16 or 17 employees. The operating budget is about $180,000, and the area involved is something less than the size of the county.

By contrast, each of you can think of a city, or county, or a special district, governed by a board of fewer members, perhaps five to nine, with many times larger budgets, many more complexities, and still they are affecting the taxpayer just as intimately. Water supply, for example, reaches right into the house, and if it isn't there in the right taste and the right quality and at the right time it affects the householder very much. Sewage systems also reach into the household, and if they don't function they can create a nasty situation. The animal pound is very close to many people's hearts. Public health matters also reach into the family in many ways, some of which are not easily recognized. Building inspections, plumbing inspections, electrical inspections—these things are very close to property owners yet are handled as a division of a larger branch of government.

Why, then, is it necessary that we have so many trustees? The answer is that it isn't really necessary. The original plan for representation is outmoded. We are densely populated, the urban areas are coming together, communications and transportation alone are shortening the intervals between all peoples. We have need for better systems. We have confidence in the large systems because they have proved they can do the job. Let us then do our part to reduce the overhead by combining districts or by amalgamating into larger organizations such as county health department, or any other organization that is able to do the job.

John E. Price
Commissioner, Lee County, Florida
Mosquito Control District

We in the Lee County Mosquito Control District in Florida feel that we can accomplish a great deal more by controlling our own area rather than being tied with the state and federal health department operations. We need help from the state and federal people, we feel they can do a lot of good. Association—yes: Control—no!

We have been able to institute some new programs in the elimination of mosquitoes—by using larvicides, helicopters, etc.—and we feel we have accomplished a lot of good. We feel we can do the job. I assume we are in the same position as most of you—short of money, and with much needed work to be done. We are working to eliminate mosquitoes, and we have had no small amount of success. I believe that if we are allowed to go ahead with our local taxing units, where we can control the operations and know what we need, we will be much better off than if we were controlled from a state or national headquarters. We can get more work done and accomplish more for the tax dollar, which we are all interested in today. From our area in South Florida we believe we are better off controlling our own mosquitoes, with the cooperation of the health department but not control by the health department.

G. F. MacLeod
Trustee, Fresno, California Mosquito
Abatement District

Let me start out by saying that I am not a "lumper." I believe that biologically we have evolved as individual organisms with some requirement for the opposing thumb in order to pick up or to grasp objects. Biologically we have evolved organs and tissues. I see no reason why a collection of these organs should profit in any way whatsoever by amassing them all and making man into purely a hand, a foot, or a head.

You undoubtedly gather the fact that I am not a strong supporter of mosquito control being a part of the health depratment—state, local, or anywhere else. We emphasize at great length our search for individual significance of the health aspects of mosquito control. We minimize that we spend most of our time on the pure nuisance relationships of mosquitoes.

The control of mosquitoes is an operational task which I feel is quite important to have established even with the ugly concept of a district. Yes, districts now seem to be under all kinds of attack, because a district does not conform in many instances to any other political subdivision. In the case of our own district, we are part county and party city. Many of you are in the same situation.

I am not sure that it is wise to divorce the spending of public tax monies from the local people who have a responsibility and an intimate association with that taxpayer. I feel, therefore, that even too large a district can become a matter of some concern, because as we grow larger we lose the intimacy which is a grass roots concept of American democracy. I do not believe that amalgamation necessarily implies economy or efficiency. Bigness of itself does not of necessity mean greater efficiency, nor does it mean greater economy.

It would seem to me that we have a real serious job ahead in maintaining the control agencies which are responsible for keeping mosquitoes under control. This is an operational matter, and we must divorce this from the research and public health aspects. We use these latter items as areas of background information, both of which are of vital necessity. The public health aspects of mosquito control are becoming more and more important—the work yet to be done within the public health departments associated with mosquito control is tremendous. We can ill afford to dilute their activities by empowering them to do the control work and drive and use their efficient peoples all over a state like California which is 1,000 miles long and has a thousand million different micro-environments.

My concept of trustees is that they are merely the guardians of the proper expenditure of funds derived from local taxes. As such, these trustees must pass judgment on the policy but not the operation of the district. If a trustee is going to choose the insecticide, the kind of vehicles and the other things involved, he is not doing his job as a trustee.

In my estimation, we would make a serious mistake by imposing one more colossal task on the public health agencies—that is, mosquito "control." Let me make it clear that these public agencies such as public health departments, research institutions, and others are the background of information on which we must rely. But, when it comes to the operational control job, that is a job for the local people.

Jesse B. Leslie
State Mosquito Control Commission of New Jersey,
Bergen County N. J.

Let me say right at the start, so that our position may be clear, that in New Jersey we would not favor consolidation.

Mosquito extermination efforts in New Jersey go back to the turn of the century. I think I can truly say that in this work New Jersey is the pioneer state in the nation and certainly was the first state in the Union to put on organized campaigns against the mosquito pest.

In 1903 and 1904 the first association was formed in this country for mosquito work and was known as the American Society for the Control of Mosquitoes. This organization lasted for some three or four years and finally disbanded. Soon after this there was formed the North Jersey Mosquito Extermination League, the membership of which consisted largely of members of the Boards of Health of New Jersey. So you see the local health departments were instrumental in getting this work started and we are fully cognizant of the close link between the elimination of the mosquito and public health. Nevertheless, Dr. Ralph Hunt who was the first president of the New Jersey Mosquito Extermination Association, said in 1914 that he felt that the primary purpose of mosquito control in New Jersey was for the economic development of the state and that its influence on health was secondary. This is a doctrine we have adhered to through the years in which we have achieved excellent results, as witness the comment of Dr. Leland O. Howard acknowledged to be the number one man in mosquito control in the entire world when he said in 1927 at the annual meeting of the New Jersey Mosquito Extermination Association: "The State of New Jersey has blazed the way and is leading the world in all practical aspects of mosquito control".

Now you probably would be interested to know just how our work has been organized and conducted in New Jersey. The basic law under which we operate is the so-called Mitchell Act, being Chapter 104 Public Laws of New Jersey, 1912. This provides for the establishment of a County Mosquito Extermination Commission in each county of the state with plenary powers to seek out and destroy all mosquito breeding within the confines of the respective counties. The act provides that at least three members of the Commission should be engaged in health work or have had some experience in this field. So you see again the correlation between the mosquito and public health was recognized. Appointment of commissioners were to be made by the Justice of the Supreme Court presiding over the courts of that county (this has been amended so that appointments are now made by the Boards of Freeholders, who are the County Supervisors). Budgets were to be submitted to the Director of the New Jersey State Experimental Station at Rutgers and when approved by him these appropriations were mandatory on the county authorities. Maximum budgets were based on a millage percentage of the tax ratables of the county. In 1912, Hudson, Middlesex, Monmouth, Essex and Union counties formed Commissions under this act and went to work. In 1913 Atlantic and Ocean joined the force of County Commissions actively at work; in 1914 Bergen came in and in 1915 Cape May was activated. The formation of these County Commissions is optional under the statute, but today 20 of New Jersey's 21 counties have adopted the provisions of the act and are busily at work.

So you see we have been at this anti-mosquito work now for over fifty years and it is interesting to note that in all those years our basic law has remained unchanged except for the method of appointment of commissioners as noted above. And during these fifty plus years the work has grown like Topsy. From modest beginnings where initial county appropriations were $15,000 or $18,000 they are now $350,000 or better and the aggregate county budgets make it a million dollar enterprise in New Jersey today.

Is this economically sound? We, in New Jersey, think that it is. Dr. Headless in 1914 said, "Judging from the increase in values which the protected areas of the state have already experienced the completion of the salt marsh drainage should result in a short period in an increase of at least $26,000,000 in taxable values."

Says Cornelius C. Vermeule, consulting engineer of New York in 1929, "I believe the state is better off today by over $350,000,000 than it would have been had there been no mosquito control."

In 1933, Mr. S. D. Walker, a prominent real estate operator and a member of the New Jersey Real Estate Board, said, "There is no question in my mind that millions of dollars in assessments have been lost in New Jersey in the past because of mosquitoes."

When I first came into Bergen County, New Jersey, to take charge of the work, people in the southern part of the county were sleeping under bed canopies. Today bed canopies are museum pieces. Bergen County has increased from a population of 200,000 so that it is now pressing a million people with commensurate tax ratables. How much of this was due to good mosquito control? We don't know, but we are sure it couldn't have happened under the old mosquito conditions.

In south Jersey, beach hotels were being abandoned and the Jersey shore, finest in the world, was lagging in development because of the mosquito.

So we organized mosquito commissions and went to work to control the mosquito to overcome this economic handicap and in 1963 the NEWARK NEWS, one of New Jersey's leading newspapers, noting the increase in tax ratables, stated that the state now has an enviable reputation as a place for comfortable living and the New Jersey shore is "ready for the thousands of visitors to whom its vacation facilities are unsurpassed."

I think as Dr. Hunt said during our formative period, our prime motivation in mosquito control in New Jersey has been economic and the health aspects have been secondary.

But as Thomas D. Mulhern pointed out in his paper on Public Health Aspects of Pest Mosquito Control published recently in MOSQUITO NEWS, "It is common for mosquito control agencies engaged primarily in the control of nuisance mosquitoes to maintain surveillance over the ecological and epidemiological factors which could contribute to the occurrence of mosquito-borne disease. Thus, when there is an apparent hazard, emergency measures can be employed in a meaningful manner. As an indication of how such a state of preparedness pays off, epidemics did not materialize at the end of World War II when malarious servicemen returned to civilian communities, some of which were formerly endemic areas."

This is pretty well borne out in New Jersey by our experience with the elimination of malaria. For the year ending Oct. 31, 1914 there were 771 cases of malaria. For the year ending Oct. 31, 1914 there were 771 cases of malaria in the State of New Jersey and 14 deaths. The relationship of the mosquito to malaria is too well known to bear discussion here. Now, while we made no all-out attack on malaria and the anopheline mosquito, we did stamp them out together with the other pest mosquitoes, until today malaria is so completely under control in New Jersey that it is practically nonexistent and the part we played in gaining this result is well recognized. In fact, the results we accomplished in the elimination of malaria and its recognized drain on the man-power of the state, with the resultant loss of time, was a factor that helped us survive the early attacks against our activities.

Similarly, we cannot discount the role of the mosquito in encephalitis. We have had our outbreaks in New Jersey. They have been serious and we have needed close cooperation from the State Department of Health in meeting these emergencies. We have received it, but we have had no difficulty with fitting our present type of organization into these emergency situations and getting the best possible results. Commenting on this, Dr. Roscoe P. Kandle, State Commissioner of Health of New Jersey says, "After the outbreak of Eastern Encephalitis in 1959, further coordination was accomplished between the several departments concerned with this disease and those concerned with mosquito control, through the formation of the Governor's Interdepartmental Committee on Disease Control. This has worked well and has presented no problems of coordination that were not successfully dealt with by this Committee."

In my opinion, complacency is never commendable. It is all right to say, "We're doing fine. Why change? We are getting results". But while that may be true, it is always possible that some changes might be effected that would get even better results. Possibly a change in organization might help. Maybe our fundamental organization could be improved. Would we be better if we were to get under the wing of the State Department of Health? A little soul searching is always good. So in 1955, at the instigation of Senator Frank Farley of Atlantic County, we did a little. Senator Farley wanted the work speeded up and he wanted a study made of the entire mosquito control set-up in New Jersey and recommendations for the future of the work.

This study commission, which contained several thoroughly experienced mosquito men, met in Trenton, New Jersey for eight weeks. They interviewed many interested persons and held a public hearing in the Senate Chamber in the State House. Among those interviewed or contacted were representatives of the County Mosquito Commissions, the New Jersey Agricultural Experimental Station, the New Jersey State Mosquito Extermination Association, the Boards of Freeholders, Fish and Game Council, State Department of Health, U.S. Department of Interior (Fish and Wild Life Service), Audubon Society, Fish and Game Council, Department of Navigation, Planning Section of Department of Conservation and Economic Development, Army and Navy, New Jersey Highway Authority, New Jersey Federation of Women's Clubs, New Jersey Health Officers Association, New Jersey State Federation of Sportsmans Clubs, Forestry, Parks and Historic Sites Bureau, Division of Shell Fisheries and the Water Policy and Supply Council. This is a pretty comprehensive cross section of people who should have ideas and convictions and the Study Commission got a great many constructive comments and suggestions. All of this they weighed carefully and then made their report to the Governor. I quote from this report:

"Under the basic law the approval of the county budgets and general supervision of the work as a whole lay in the Director of the New Jersey Agricultural Experimental Station.

"Based on the studies we have made, we believe that this system is fundamentally sound and should be continued. We feel that over the years tremendous progress has been made and that it is as practical as any that can be devised. However, we feel that certain changes can be made to advantage to strengthen and improve the work as now being conducted in this state; primarily that there should be greater central control, more and better research and greater power of enforcement."

Out of this evolved the State Mosquito Commission and the new research laboratory at New Brunswick so that the work as formerly conducted was given a coordinating central force to correlate and encourage state aid matching fund projects, water management installations and regional projects which traverse county lines.

You will note that among those with whom the Study Commission discussed improvement of mosquito control methods was the State Department of Health. The question was raised as to whether a possible consolidation of mosquito control, agencies into the State Health Department would be advantageous and the reply was negative.

That was in 1955, but our State Department of Health has had no change of mind since then as is indicated by a letter the writer of this paper received from Roscoe P. Kandle, M.D., State Commissioner of Health, under date of January 18, 1967, in which he says: "The New Jersey State Department of Health is still in agreement that the county extermination commissions are and should be the primary, responsible agencies for mosquito control in New Jersey. The present plan for having these county commissions working under the direct guidance of the State Agricultural Experimental Station and their programs coordinated under the State Mosquito Control Commission is working well and should be continued."

Dr. Kandle goes on to say: "Knowing of the proposed Federal Bill, HR. 16841, 'Mosquito Control Act of 1966', I want you to know that if such a proposal became a law we would see no problem in New Jersey in the Public Health Service recognizing the state and county mosquito extermination commissions as the state agencies to receive grants-in-aid on a matching basis to carry out state and local mosquito control programs. The question as to whether all mosquito control should be done by the Health Department or by special agencies does not appear to be worthy of any discussion. Experience in New Jersey shows that mosquito control work can be done most effectively by the extermination commissions, while in Florida and some other states such control work is done effectively by programs in the health departments. Regardless of whether mosquito control is viewed as an economic problem or a health problem, it would seem that our present plan of organization is best for New Jersey at this time."

So there you have it. We feel that we have a sound type of organization that is getting results. The State Department of Health doesn't want to adopt us and we cannot see that our efficiency would be increased if they were to do so. So, as I said at the start of this paper, as far as New Jersey is concerned we would not be interested in any move to consolidate our mosquito control agencies, as presently constituted, with the health departments.

RESPONSES

GLENN M. STOKES
Director, Jefferson Parish, Louisiana Mosquito Control District

On August 23, 1966, A.M.C.A. President Jay Graham appointed the following members to the Legislative Committee: Dr. Lewis Nielsen, Fred Bliss, John Brawley, Robert Armstrong, Dan Gorman, and myself. This committee was charged by President Graham "to study House Resolution 16841, and to determine, if possible, what the A.M.C.A. thinks about it, and to make some recommendations to A.C.M.A. for action."

House Resolution 16841 had been introduced into the U.S. House of Representatives by Congressman Edward Patton of New Jersey in the second session of the 89th Congress. This bill was referred to the Committee of Interstate and Foreign Commerce. However, it never received a public hearing in the 89th Congress. In January, 1967, House Majority Whip Hale Boggs reintroduced a similar bill, called "The Mosquito Control Act of 1967." This bill is essentially the same as the old, except that $3,000,000 granted for research and assistance in Title I of the earlier bill is reduced to $2,800,000.

The A.M.C.A. Legislative Committee has studied this bill and has submitted a report to the A.M.C.A. Board of Directors which we feel is a consensus view of the committee members, the A.M.C.A., and the various state mosquito control associations. This consensus view is that HR 16841, as it is now written, is neither good for the overall welfare of mosquito control in the United States nor for the A.M.C.A. in general. Many of those expressing opinions indicated qualified support of Title I, which provides federal monies to the U.S. Surgeon General's office for research and technical assistance not to exceed $3,000,000 in any one fiscal year. Only two respondents indicated approval of the entire bill as now written. There was little enthusiasm from the majority of respondents for Title II, which provides for funds to states not to exceed 50% of funds expended, or $1,000,000, whichever is the lesser. The majority of respondents indicated the need for clarification of the bill in general. The majority indicated that some provisions of the bill are already being served through existing agencies and programs.

This legislation dates back to the early 1950's. At that time, Senator Holland of Florida apparently started this particular bill on its way. In 1956 Senator Long of Louisiana introduced a similar bill; however, it applied to the southern states only. Congressman Auchincloss of New Jersey in 1961, Congressman Downing of Virginia in 1963, Congressman Boggs of Louisiana in 1963, Congressman Patton in 1966, and Congressman Boggs again in 1967 have kept this "bill" alive. I have received further word from Congressman Patton that he intends to introduce yet another similar bill in the 90th Congress, so there possibly will be two bills in this current session of the 90th Congress.

In general, the findings of the committee were:

1. The bill is not well written, having many inconsistencies and ambiguities;

2. The bill should be rewritten;

3. Title I is already being done through existing structure and apparatus, and does not consider "areas of principal need" in mosquito control.

4. Title II does not consider these "areas of principal need," and there are no provisions to keep existing mosquito control agencies which are adequately financed from applying for these funds, inflating their budgets and receiving these funds—thus encouraging rather than discouraging wasteful spending;

5. There is undue opportunity for politics to enter in at the district court level. (The district court as provided by this bill is the agency that enforces it. It is the watch dog.) We feel that politics at all levels —the district court level, the state level and the local level—should be excluded explicitly in the bill; and

6. In view of the foregoing observations and questions, it is recommended by the A.M.C.A. Legislative Committee that it would be premature at this point to reach a decision on this bill until it has been significantly revised.

The Legislative Committee recommended that the authors of the bill—"The Mosquito Control Act of 1966," and now "The Mosquito Control Act of 1967"— be contacted and asked to consider rewriting the bill.

The committe asked the Board of Directors, which met on February 5, to consider the following questions and state their feelings:

1. Is there any real need to create new policy and programs for research and technical assistance?

2. If there is need, does this indicate the inadequacies of existing agencies, which are already set up and potentially available, or does it indicate the lack of funds for these agencies to prosecute their work?

3. Instead of creating new structure, why not streamline and improve the efficiency and effectiveness of these existing agencies, with bigger appropriations for them, if justified?

4. Is there a need for matching grants to states for mosquito control? If there is a need, why set up new structures and procedure to administer? Why not allow existing, longtime agencies with administrative and fiscal experience to provide assistance on a whereneeded, as-needed basis? This kind of assistance sets up a priority of need, not a priority of request.

5. If this bill is sound and needed, why has it floundered in Congress for over 12 years?

I doubt if there is anyone here today—A.M.C.A. member or anyone interested in the welfare of mosquito control—who is against more research, technical assistance and aid to new mosquito control programs or existing programs. The question before us is, however, how to provide these things.

The A.M.C.A. Legislative Committee feels that HR 16841, as written, does not provide the vehicle for bringing about improved mosquito control. This report has been submitted to the A.M.C.A. Board of Directors. The matter was tabled due to mixed feelings among the board, and it will be considered by the new Legislative Committee of the next A.M.C.A. administration.

SPECIAL REPORT

EMERGENCY MEASURES EMPLOYED IN THE CONTROL OF ST. LOUIS ENCEPHALITIS EPIDEMICS IN DALLAS AND CORPUS CHRISTI, TEXAS, 1966

John W. Kilpatrick
Aedes aegypti Eradication Program
Public Health Service, Savannah, Ga.

and

Claude T. Adams, Sr.
4500th Air Base Wing (TAC)
Langley Air Force Base, Va.

Abstract

Studies in South Carolina, Florida, and in Puerto Rico have indicated the ultra low volume aerial application of malathion to be highly effective against the adults and larvae of *Aedes aegypti.* These studies indicated that:

1. Application rates of malathion (95 percent techencal) at three liquid ounces of active ingredient per acre effectively controlled both adults and larvae.
2. Particle size for satisfactory biological effect is in the range of 50 to 60 microns MMD.
3. Deposition of particles should be at least 10 per square inch, preferably 20 or more.
4. Applications should not be attempted when wind velocities are 10 mph or higher, or when temperature inversions exist.
5. Application of malathion at three ounces per acre with particle sizes in the 50 to 60 micron MMD range did not affect paint surfaces on automobiles.

When the St. Louis encephalitis epidemics of Dallas and Corpus Christi, Texas, occurred in August, 1966, the ULV aerial application technique was utilized in an attempt to break the virus transmission chain by drastically reducing the population of adult *Culex quinquefasciatus*, the vector species. By means of six U.S. Air Force C-123 aircraft, three from the 4500th Air Base Wing (TAC), Langley Air Force Base, Virginia, and three from the 4408th Combat Crew Training Squadron, Hurlburt Air Force Base, Florida, about 475,000 acres in Dallas and Dallas County were sprayed during an eight-day period. Rain and high winds prevented spraying during two of the eight days. Approximately 12,000 gallons of technical malathion (95 percent) were used. In Corpus Christi, Texas, 100,000 acres were similarly treated with approximately 2,500 gallons of technical malathion.

Studies by the Arbovirus Infections Unit, National Communicable Disease Center, indicated a greater than 90 percent reduction in counts of adult *C. quinquefasciatus* mosquitoes collected in designated resting stations. Furthermore, a sharp decline in the vector infection rate was also demonstrated. Prior to treatment, these workers found that approximately one out of every 160 mosquitoes was infected, with 62 St. Louis virus isolations made from 10,000 specimens tested. In contrast, only two positive mosquitoes were found in 58,000 tested during a 45-day post-spray period.

Human cases of encephalitis rapidly declined approximately 14 days (one incubation period) after spraying was initiated. Although one cannot be positive that the decline of human cases was due to the ULV aerial spraying, the sharp reduction in mosquito infection suggests that further transmission would have been very unlikely.

SUBMITTED PAPERS SESSION

CONCURRENT

TUESDAY, FEBRUARY 7, 8:30 P.M.

RICHARD F. PETERS, *Presiding*

THE FLIGHT HABITS OF *ANOPHELES FREEBORNI* AITKEN

STANLEY F. BAILEY AND DAVID C. BAERG

University of California
Department of Entomology, Davis, Calif.

The majority of anopheline mosquitoes are non-migratory. Throughout North America there are recognized, in the broad sense, fifteen species of *Anopheles* among which there are two well-known malaria vectors. In the eastern half of the United States *A. quadrimaculatus* Say, a nonmigratory species, is of major importance. In the western area its counterpart, *A. freeborni* Aitken, is a dominant mosquito of the arid and semi-arid valleys. The dividing line between these two species is approximately the Texas panhandle, which coincides with the 15 inch isohyet of April-September. Freeborn and Bohart (1951) consider the eastern limit of *freeborni* to be the continental divide. Apparently the eastern species does not tolerate the hot, dry summers of the Southwest and far western states. In contrast, *A. freeborni* thrives very well in the semi-arid region but avoids flights away from the breeding areas in the summer. Ecologically, the western malaria mosquito stands alone among the North American anophelines in that it has a definite fall migratory phase.

The subject of the flight and dispersal of anopheline mosquitoes world-wide has been reviewed by Eyles (1944). Various authors have reported maximum flight ranges, based on experiments with marked specimens, of from 0.31 to 11.25 miles for different species. Those species found in certain semi-arid climates, such as *maculipennis* Meigen in Algeria, Sicily, Macedonia, and Russia, *superpictus* Grassi in Calabria and *sacharovi* Edwards in Palestine have been reported to have definite fall prehibernation flights of 3 to 8 miles, and possibly as far as 11.25 miles in Russia (Shipova, 1936). This latter worker appears to have conducted the only experiments known to us which involved the release of marked mosquitoes before hibernation, together with an attempt to recapture them in their overwintering sites. Recently Ouraishi, *et al.* (1964, 1965) and Abdel-Malik (1966) have reported on the flight range of *Anopheles* species in Iran and listed the newer references.

This prehibernation flight habit of certain anophelines appears to have developed as a result of a survival need. This need stimulates them to seek protected overwintering sites above or away from winter flooded areas, and additionally provides warm blooded hosts (forced to move to higher ground during floods) on which to nibble during warm days. Freeborn has discussed this interesting phase of the western malaria mosquito (1945, and in Boyd, 1949) and has advanced the theory that "This fall and spring migration is apparently an adaptation to breeding waters whose extent decreases throughout the active season without replenishment. The migration allows them to retrace the path that the species has followed as water became progressively scarcer during the preceding summer." Be that as it may, the habit of *freeborni* entering man's abodes in the fall in large numbers and creating a widespread, irritating nuisance (as well as in former years locally transmitting malaria) has directed the attention of many entomologists to this seasonal activity.

In addition to any "appetential drive" (Provost, 1952) or "wanderlust" (Freeborn 1945, 1949) this mosquito has to seek winter quarters as normal agricultural practices in the rice-growing districts of California force them to leave the immediate vicinity of the fields to survive. Early in September the fields are drained and harvested. Following harvest, weather permitting, the majority of the stubble fields are burned and plowed. Other adjacent crops such as beans, alfalfa seed, tomatoes, safflower, wheat and barley also are harvested, and the crop refuse plowed under if not prevented by early rains. The result is that often there are many square miles of barren fields in which there are no resting sites for mosquitoes. Thus, the movement of *freeborni* is to whatever farm buildings, brushy areas, or bridges that may be present in the vicinity. Certain "flyways" appear to exist, as evidenced by heavy concentrations of adults. These areas, however, are extremely difficult to map without an intensive study of local winds, and without visiting a large number of collecting stations daily during September and October. Since the first studies made by Freeborn (1921) of this mosquito, many entomologists and residents have reported long fall flights across dry stretches of fields and hills. Rosenstiel (1947) by means of adult resting station counts during the fall migration concluded that the migrants travelled as far as 26 miles in a southerly direction away from the rice fields. One of the most impressive cases of a fall invasion of the foothills was seen by D. A. Eliason and the senior author on November 9, 1962 when working on a flight range study of *Culex tarsalis* Coq. In searching for overwintering sites of *C. tarsalis* we found an abandoned, empty, cement reservoir with a wooden cover on a dry, wooded ridge of Brush Mountain. This location was about 1100 feet elevation in southwestern Colusa County, and 11 miles west of the nearest rice fields. Four species of adult mosquitoes were found in this isolated resting site.

Many female *A. freeborni* were resting therein and could have come only from the valley.

In the foothills of the Sierra Nevada Mountains, as well as hills to the west of the valley, breeding occurs in farm ponds, reservoirs, and irrigation ditches. The surrounding countryside is wooded, and such confined populations migrate but a short distance to find suitable overwintering sites. Similar conditions occur also in the Willamette Valley of Oregon, formerly a well-known malarious area. Throughout the range of *A. freeborni* (Stage, *et al.*, 1952) local conditions will vary widely such as in the open sage covered areas of eastern California (Freeborn, 1926), Oregon and Washington (Rush *et al.*, 1958; Harwood and Halfhill, 1960) and in the mountain valleys of Idaho, Utah and New Mexico (Rees and Harmston, 1946; Barber *et al.*, 1929). In each area the distance, direction and extent of the fall migration will vary according to the topography, winds, and the proximity of adequate overwintering niches to breeding sites.

Since earlier work on the flight range of this mosquito in the main was observational, we have attempted to verify some of the generally accepted accumulated biological information by means of marked specimens. The techniques and experience gained from field studies with *Culex tarsalis* Coq. (Bailey *et al.*, 1965) were used to advantage. As a part of the overall study of the ecology of anophelines in northern California (Bailey and Baerg, 1966) during 1963-67 we have conducted studies on flight range which are described below. We believe this series of 18 experiments, during which we attempted recovery of marked mosquitoes over a continuous period of about six months for each of four years, is more extensive than previously attempted. Other information on the flight habits of *A. freeborni* also is included. This report attempts to answer in part some of the questions posed by the suggested "rice field project" outlined by Sperbeck *et al.*, (1951).

Flight Habits

The flight habits of this mosquito vary at different times of the year. Therefore, it is convenient to separate the adult females into phases according to the seasonal changes in this activity. In the summer there is no indication of a migratory instinct. These individuals can be termed *Phase One*. During the period of high temperatures and low humidity the adults remain very close to the breeding areas. Swarming and mating takes place over or at the edges of the rice fields, ponds, and seepage ditches (Sperbeck, *et al.*, 1951). No significant flight away from the major breeding areas occurs unless the water source is altered by drying or pollution. The resting adults are scattered, and as a result the numbers usually collected in nearby resting sites is small in relation to the density of larvae. Close observation shows many adults resting on or in cracks of damp soil, in the shade along the ditches, in animal burrows (Harwood and Halfhill, 1960), in grass, tules, and on the bark of willow and other trees near the ground. Breeding populations in ponds and reservoirs in the foothills and mountains remain isolated. Freeborn (1945) wrote "The midseason flight range is generally restricted to a mile radius," and Markos (1950) believed the males seldom went more than one-fourth mile from their breeding site.

In late August, even before the rice harvest is begun, the adults start to move out of the summer breeding areas. This is evidence of the onset of *Phase Two*, or the fall migratory phase. It appears to be divided into two stages: (a) the congregating period (Rosenstiel, 1947), in which there is a rapid increase in numbers of both sexes in nearby, large, open shelters in early September; and (b) the migratory or dispersal period which becomes evident shortly thereafter by the presence of large numbers of adults in residential areas. Freeborn (1932), who first referred to this phase as "prehibernation" individuals, stated they invade localities in which they previously have been totally absent. The time of this invasion varies from year to year and appears to be accentuated by north winds. The initiation of this movement seems to be independent of temperature. Depending on the location of the breeding sources in the lower Sacramento Valley. the flight commonly is in a north-south direction. The removal of all adults from resting stations, and their subsequent inflow, shows that there is a continual movement of adults passing a given point during this migration, which may continue throughout October. We believe that maximum distances are reached during October. By early November the highest numbers have accumulated in the preferred resting sites. Some seasons this fall migration is rather dramatic, as that which took place in 1961 (Table 1) from the rice fields to the city of Woodland about 10 miles to the south. A very strong north wind, up to 29 mph had prevailed August 30 through September 1, previous to the influx.

Additional data were obtained in the Knights Landing community on the seasonal movement of *A. freeborni* from rice fields to adjacent residential areas. In 1963-64, the porch of an abandoned house in the northern part of the small town, not over one-half mile from the closest rice field, was used as a collecting station. From March 19 to June 4, 1963 no anophelines were present at this resting site. The collection data, obtained by B. L. Hoffmann, for this location, are as follows:

		Males	Females
June	4	0	4
	10	0	2
	17	0	0
	24	0	4
July	1	1	6
	8	0	2
	15	0	1
	22	0	10
	29	4	18
Aug.	5	2	11
	12	1	2
	19	4	18
	27	10	23
Sept.	1	16	17
	9	9	39
	16	45	131
	23	67	108

It can be seen from these collections that the major movement from the breeding areas to more protected sites began about mid-September. A moderate northwest wind up to ten mph occurred on September 14, which again showed its influence on fall flight.

Infiltration into the foothills laterally from the valley normally is somewhat slower and the numbers penetrating the canyons much smaller than those found in the valley stations (Table 2).

As the weather gets colder by mid-November all the males have died (see Tables 6, 8, 11 and also Freeborn, 1921), and the females move to the more protected niches free from wind, rain, and frost formation. This is the winter "hibernating" form or *Phase Three,* which is present from November to March. In California this mosquito has been described briefly by Freeborn and Aitken as in "hibernation," during which time the adults are "active" throughout the winter, biting readily outdoors on warm days (see also Gjullin *et al.,* 1963). The threshold for strong positive flight is about 50°F. Rush (1962) reported that *freeborni* cannot become airborne at 32°F. The lowest daytime temperature we have recorded at their winter resting sites is 35°F (December 29, 1966 at Davis). No specific counts or record of movement previously have been presented during the winter season to illustrate this "frequent change in place of refuge" (Freeborn, 1921). In the 1964-65 season we collected resting stations regularly in the north-south oriented Capay Valley in connection with fall flight study (Table 6). As pointed out elsewhere, *freeborni* can rarely be found in the summer in this narrow valley isolated from the rice fields. In the fall, as the rice matures, large numbers "invade" the area from the east. From 5 to 19 stations were collected each week from August 11 to March 18. All the mosquitoes were removed from each site at each visit. Therefore, those specimens taken after the first collection moved into the resting sites from other locations at unknown distances during the six days (and seven nights) intervening between visits. Data from two specific stations will serve to illustrate the actual movement or relocation as it might be termed. Station No. 12 was a corrugated metal culvert located in the foothills at 320 feet elevation on the west side of the valley among oak trees and brush. The creek flowing through the culvert was completely dry from July to late December. The nearest rice field was 10 miles to the east beyond a range of hills with a maximum elevation of 1820 feet. The weekly collections 1964-65 (all females) were as follows:

September	29	72	January	5	Flooded
October	6	106		12	Flooded
	13	41		19	Flooded
	20	34		26	Flooded
	27	31	February	4	0
November	3	22		11	2
	10	23		18	3
	17	12		25	3
	24	10	March	4	0
December	1	9		11	0
	8	3		18	0
	15	7			
	22	Flooded			
	29	Flooded			

Station No. 3, a release site, was a cement culvert located under a paved road near the mouth of the valley and 7.5 to 12 miles west of the nearest rice fields. The numbers collected at this station were greater as shown below:

Aug.	7	0	December	1	19
	25	10 (plus 6 ♂♂)		8	12
Sept.	1	76 (plus 9 ♂♂)		15	11
	11	220 (est.)		22	Flooded
	15	197 (est.)		29	Flooded
	22	400 (est.)	January	5	Flooded
	23	500 marked specms. released		12	35
	29	400 (est. not collected)		26	11
Oct.	13	29 - one marked (20 days after first release) 900 marked specms. released	February	4	7
				11	16
				18	7
				25	4
			March	4	1
Nov.	3	113		11	0
	10	75 (one marked) 28 days after second release		18	0
	17	35			
	24	36			

Table 1. *Anopheles freeborni* adults collected from artificial resting units (red boxes), Yolo County, California 1961.

Month	Week	Rice field[1] (Near Knights Landing) Avg. no. per box Males	Females	City[2] Woodland, 10 miles south of rice fields) Avg. no. per box Males	Females
June	3	2.3	1.4		
	4	3.0	2.6		
July	1	3.5	2.4		
	2	2.8	3.2		
	3	2.9	4.0		
	4	30.7	13.9		
August	1	8.5	3.0		
	2	2.3	1.5	0	0
	3	10.4	4.2	0	0
	4	12.7	8.5	0.25	0.25
September	1	5.5	5.7	20.0	43.7
	2	6.6	11.2	8.8	27.0
	3	1.7	1.8	8.2	24.0
	4	1.7	1.0	24.5	30.0
October	1	2.4	0.5	18.0	14.2
	2	0.7	01	3.0	16.0
	3	0.1	0.3	4.5	20.0
	4	0.7	0.3	1.0	5.5
November	1	0.0	0.1	0.0	3.2
	2			0.0	1.2
	3			0.0	0.25
	4			0.0	0.0
December	1			0.0	0.5
	2			0.0	0.0

[1]42 collections June 16 to November 7 from an average of 13.7 boxes per night.

[2]21 collections August 8 to December 12 from four boxes per night.

Table 2. *Anopheles freeborni* adults, collected in eastern foothill stations, Placer County, California. 1965-66.

	Station 1	Station 2	Station 3	Total of
Elevation (feet)	400	600	1000	
Distance from release point	10.5 mi.	12.0 mi.	14.5 mi.	three stations
Oct. 5	18[1]	2	0	20
Oct. 19	56	9[2]	5	70
Nov. 4	33	15	16	64
Dec. 2	45	42	11	98
Jan. 13	36	12	12	60
Feb. 10	19	10	8	37
Total	207	90	52	

[1]Including one male
[2]Including one male

These data show clearly that large numbers move about during September-November particularly. No specimens were removed from Station No. 3 for several weeks following the first release of marked adults to allow adequate time for dispersal. Strong north winds occurred on the nights of September 20 and October 1 and 2. Light north winds blew the nights of September 2, 15, 21, 21-22, and 24 and October 3, 17, 30. After 20 days (October 13) only 29 individuals, including only one of the 500 marked specimens were found at this location. Following the second release of 900 marked mosquitoes (after all specimens were removed, i.e., the 29 mentioned above) an even greater movement from this site took place. By November 3 only 113, all unmarked, were taken. However, a week later, and 28 days after the second release, another marked individual was collected, having flown back into this resting site. It is not known from which release this specimen originated or how far it had traveled in the intervening weeks. As colder weather arrived the numbers dropped rapidly, although continual movement of new individuals into this culvert took place until the overwintering phase of the seasonal cycle was completed in early March. We believe this is the first specific proof by means of marked specimens of the winter flight of this anopheline.

The spring dispersal phase we shall call *Phase Four.* Dispersal of the overwintering females in the spring appears to be much more limited than in the previous fall ,and lacks specific direction. From about mid-January to late March in some years (see Table 8), depending on the temperature, the number seeking blood increase and those remaining in the winter resting sites diminish. The blooded individuals fly very little, and when gravid oviposit in the nearest favorable site. The flight of the depleted (hungry) overwintering females appears to be very local as they seek the nearest blood source. Windy periods undoubtedly further extend their range, which results in egg laying many miles from their focus of origin the previous fall. Release-recapture experiments at this time of year would be extremely difficult to conduct and we have no data on distance and direction of flight by this phase.

Fall Flight Range Study

As mentioned earlier, investigations by other workers on the flight range of *A. freeborni* have been chiefly observational. To our knowledge no experiments utilizing marked specimens of this species previously have been conducted. We have carried out four experiments on this aspect of the biology during the fall seasons of 1963-66. The specific objectives and location of each experiment have been different as described below. The principal purpose of this part of the ecology project was to ascertain the distance, direction and extent of the fall movement of this mosquito out of the rice-breeding area in the Sacramento Valley.

All mosquitoes used in the release experiments were field-captured. They were collected with a motor-driven suction apparatus described elsewhere by the senior author (1966). The mosquitoes were held and transported to the release sites in screened cages or screen topped 3-gallon cardboard ice cream cartons. Water was provided only when the specimens had to be held for several days to accumulate sufficient numbers for a release. The number of mosquitoes was estimated using the method described by Dow and Reeves (1965). Marking powders and the technique of dusting have been discussed and illustrated by Bailey, *et al* (1963, 1965). The powders employed did not shorten the life or impair the flight of the treated mosquitoes. Weather data was taken at the time of the release.

Weekly collections were made following the releases with the exception of the first experiment. The collecting stations utilized were those most accessible, and those found by repeated visits to be the most favorable to the mosquitoes. Finding the largest numbers obviously increased the chances of recapturing marked individuals. When possible, and during a time interval of not more than 30 minutes, all mosquitoes were removed from a station at each visit. The suction apparatus was employed for the larger collections, and a flashlight battery operated modified "dust-collector" or a breath aspirator tube was used for the smaller samples. The specimens were killed in the field with chloroform and examined in the laboratory the same day under an ultra violet light. Exception or variations of this method are given below under the specific experiments.

Importance of wind in fall migration. We have previously analyzed the summer wind patterns in the lower Sacramento Valley in relation to the flight range of our other important rice field mosquito, *Culex tarsalis* (Bailey *et al*, 1965). In July and August the per cent of south wind during the night hours was found to be 88 and 85, respectively (1954-58). On the other hand, the amount of north wind in these months was only two and one per cent of the total. There is a major difference in the motivation of flight by *C. tarsalis* during the summer months in contrast to that of *Anopheles freeborni* in the fall. In the summer *C. tarsalis,* in attempting to find a warm blooded host, orients into the wind to receive the odor signal. We found that this mosquito moved chiefly down wind with winds above 4 mph. At lower wind velocities dispersal was in all directions, and actually moving upwind against winds up to 2.9 mph. In contrast, *A.*

freeborni is a stronger flier than *C. tarsalis*, and the fall flight motivation is that of seeking a suitable hibernation site. A very low percentage take blood in September thru December. Therefore, we have tabulated the two prevailing winds above 4 mph for the hours 6 p.m. to 6 a.m. for the fall flight periods, September and October, for 1963-66.

It can be seen from Table 3 that there is more north wind in these two fall months than during the summer. Even more noticeable is the decrease in the amount of south wind and the dominance of light and variable winds. In other words, during the fall migrating period *A. freeborni* encounters strong winds both from the north and south which may influence the direction of their movement. From half to three-fourths of the night hours, however, the wind is shown to be of such low velocity that migration could be in all directions. This appears to have been the case in 1965 and 1966 as shown by the pattern of recovery of marked mosquitoes. The wind data summary here presented is from the records of Dr. Herbert B. Schultz, Department of Agricultural Engineering, Davis. Local winds in the valley will vary somewhat both as to direction and velocity. Also, the fall movement is a gradual process, i.e., all the mosquitoes do not leave the rice fields the same day — or week — at which time there may be a north (or south) wind. The great percentage of rice acreage is to the north of the heavily populated area lying between Roseville — Sacramento — Davis and Woodland. Thus, the northerly winds which tend to "push" the migrating population of mosquitoes southward perhaps give the false impression, that north winds only bring in mosquitoes. Instead, there are simply fewer mosquitoes to be brought in with a south wind. Our data from the 1965-66 experiment (see Table 9) shows this general movement.

First experiment, 1963-64. The pilot release-recapture experiment with marked *A. freeborni* adults was conducted on the west side of the Sacramento Valley near Williams, Colusa County. This community is located in the central western portion of the major rice-growing area of the state. The objective of this experiment was to determine the extent of the movement from the valley breeding sites to the foothills in the fall which normally does occur. The initial release point was located seven miles west of Williams. Six miles of dry pasture land intervened between the nearest breeding site and this release point. The site at which the mosquitoes were released was a double cement culvert, square in cross-section, under State Highway 20. Many swallow nests offering ideal resting niches were present on the walls. Small residual pools of water remained in the creek which flows eastward from about 1200 feet elevation. No *Anopheles* larvae were found in these pools. On August 19, only one female was found in this culvert, but by October 1 there were 17 males and 149 females present. The canyon utilized in this experiment opens into the valley at this culvert site, which has an elevation of 335 feet. Westward the creek follows the highway for about 2.25 miles up to 640 feet, then south for about five miles to 1135 feet. The line of collecting stations followed the highway west for an additional four miles to 1725 feet near the Lake County line. Eight culverts and one bridge along this route were employed as collecting stations.

For the release, adult *freeborni* were taken from a fall congregating site near the Sutter Bypass about 28 miles to the east (the same day as marked and released). They were dusted in screen cages covered with wrapping paper at the site and liberated about 15 minutes later. This first release was made up of two lots of 2000 adults each; one lot was dusted with a fluorescent powder and the other with a metallic bronzing powder for comparison. One lot was released in each section of the culvert at 2:20 p.m., October 14. None of the adults immediately attempted to fly out. Three days later with the aid of a flashlight it was noted that the two lots had "mixed," as specimens were seen resting in the opposite side of the culvert from that in which they were freed.

At the release locations a 6-foot strip in the center of the culverts was collected. These token collections were made to determine the period that the marked mosquitoes remained at the site and were not included in the tabulation of recaptures. In all other stations all adults present were aspirated and removed at each visit. Each lot was examined under an ultra violet light as well as visually with a microscope in the laboratory to detect the presence of the marking powders. Three males only were collected; two at station No. 1 and one at station No. 2 in October.

Table 3. Summary of winds (>4 mph) 6 p.m. to 6 a.m., September-October, 1963-66—Davis, California.

	SEPTEMBER					OCTOBER				
	North		South		Calm, variable, or <4 mph	North		South		Calm, variable, or <4 mph
	Hrs	Percent of evening hours	Hrs	Percent of evening hours	Hrs	Hrs	Percent of evening hours	Hrs	Percent of evening hours	Hrs
1963	7	1.9	75	20.8	278	0	0	76	21.0	296
1964	34	9.4	109	30.2	217	30	8.0	66	15.0	276
1965	58	16.1	72	20.0	230	21	5.6	44	11.3	307
1966	28	7.7	101	28.0	231	42	11.3	48	13.1	282
Totals	127		357		956	93		234		1161
Four year avg. (per cent)		8.8		24.8	66.4		6.2		15.7	78.1

On November 26, 1500 mosquitoes were collected at the same place as for the first release and held outdoors for five days. This lot was freed at station No. 6 (1016 feet elevation) at 11:45 a.m. Fluorescent powder of a different color was used in this instance. This culvert was of the same type but with one passage, longer, darker and also with many swallow nests. By this time the weather was cold and ice formed on nearby pools almost nightly.

A total of 5500 marked mosquitoes were released and only 1731 "wild" specimens collected during the period of the experiment which extended from October 17, 1963 to March 19, 1964. Fifty-nine collections were made with an average of 29.3 mosquitoes per collection. The average total number per station was 192.

Four marked females were recaptured from the October release as follows: one marked with metallic powder at Station No. 2 (7/8 mile west) on November 12 or 29 days later and three, similarly marked, at Station No. 3 (1.75 miles west) on the same date. At the October release site marked specimens were observed (at rest) as late as December 10, and of the token specimens recovered and examined in the laboratory, marked individuals were present up to January 29 or 107 days. A total of 78 marked female mosquitoes were identified from this site, 54 of which were collected or observed during the first two weeks after release. From the release of November 26 no specimens were collected away from the station serving as the release point At this site 166 marked specimens were seen up to January 2 and an additional 28 examined in the laboratory up to February 20 or 86 days later. The percent of recapture away from the site from the first release was 0.1 and zero for the second. The collection data for this experiment are given in Table 4. During October, 1963 there were no north winds stronger than about 4 mph.

From this experiment we learned: (1) that fall dispersal of *A. freeborni* from the rice area to the adjacent foothills does take place and the numbers are not large; (2) the males do not migrate nearly as extensively as the females from the valley but do fly as far as 6 miles; (3) after the middle of November the movement is very limited; (4) many mosquitoes remain in the same resting sites in this hill area all winter; (5) released specimens will fly as far as 1.75 miles westward up the canyon in three days. Further, we learned that the dispersal pattern into the hilly wooded areas could not be followed adequately (from the experimental standpoint) because of lack of accessible, good resting sites and the establishment of predetermined collecting stations which could be visited throughout the winter. This observation is in agreement with Loomis and Green (1959) who have shown previously that the greatest density of adult *freeborni* occurs in artificial resting places.

Second experiment, 1964-65. This experiment was a continuation of the one preceding, but in a foothill valley area, also on the west side of the Sacramento Valley, which was more accessible and in which the fall flight pattern could be studied more easily. The area chosen for this release-recapture study was the Capay Valley of Yolo County. This valley, oriented generally in a north-south direction, is about 14 miles in length, one-half to two and a half miles wide, and varies in altitude from 200 to 480 feet from south to north. Almonds are the principal crop in this area

Table 4. Adult *Anopheles freeborni* collections in flight range experiment 1. Highway 20, west, Colusa County, California. 1963-64.

Station	1	2	3	4	5	6	7	8	9		
Elevation (feet)	335	380	640	790	817	1016	1135	1055	1725		
Airline distance and direction from release point (miles)	0	0.87W	1.75W	2W	3.25SW	4.25SW	6.75SW	7.25SW	8.5SW		Avg per
Date										Totals	Sta
Oct. 17	120[1]	87	N.C.[3]	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	207	103
Oct. 28	116	123[2]	29	4	8	69	8	2	11	370	41
Nov. 12	110	68*	21*	15	N.C.	56	11	N.C.	5	286	41
Nov. 26	124	25	35	flooded	flooded	43	2	flooded	10	239	40
Dec. 10	99	26	23	11	0	8	1	flooded	1	169	21
Jan. 2	93	10	flooded	21	10	20	7	3	1	165	21
Jan. 29	93	20	flooded	4	6	27	N.C.	flooded	0	150	25
Feb. 20	91	8	flooded	2	0	43	0	flooded	0	144	21
Mar. 19	1	1	flooded	0	0	3	N.C.	N.C.	0	5	0.8
	847	368	108	57	24	269	29	5	28	1735	

[1]In addition 2 males, not included; all other specimens were females.
[2]In addition 1 male, not included; all other specimens were females.
[3]N.C. — not collected.
*Marked specimens recaptured.

Table 5. Summary of releases and recaptures of marked *Anopheles freeborni* adults. Flight range experiment 2. Capay Valley, Yolo County, California. 1964-65.

Date	Valley location	Estimated no. released (females only)	Marking dust color	Conditions[1] Temp. (°F.)	Conditions[1] Time	Recaptures No.	Recaptures Days after release	Recaptures Distance and direction from release point (miles)
Sept. 29	North	1000	Green	70	10 am	1	121-142	17.5SSE
Oct. 20	North	400	Green	69	10 am			
Sept. 22	Center	500	Gold	90	10 am	1	35-49	5.75SSE
Oct. 6	Center	1500	Gold	79	10 am			
Sept. 23	South	500	Pink	94	7 pm	0	0	
Oct. 13	South	900	Pink	62	9:30 am			
		4800				2		

[1]The air was calm at the time of all releases.

which is hot and dry for about six months of the year. A single year-round flowing water course runs along the eastern portion.

Anopheles breeding in this valley is very minimal and restricted to rather local "pockets" where *punctipennis* is found and to many algal mats supporting *franciscanus* abundantly in shallow portions of the stream's gravelly margin. Larvae of *freeborni* are extremely scarce and adults were not found in resting sites until August 25, with the exception of one specimen taken in July. During September there was the usual fall influx of mosquitoes; *freeborni* making up 97 to 100 per cent of all adults collected. The only explanation possible (which has long been the belief of the residents) for this very great increase is flight from the Sacramento Valley rice fields 7.5 to 14 miles to the east and northeast beyond a range of hills which have a maximum elevation of 1820 feet. Prevailing winds from the south and southwest pass over an extensive wooded, mountainous area and do not "*bring in*" anophelines. Winds from the east are extremely rare. Seasonal north winds, very common in the fall, appear to act as the major agent in this influx of *freeborni* in September and October. Strong support is given to this contention by the fact that recaptured marked specimens in this experiment were taken only at stations to the south of the release points (or at the release points themselves).

Six releases of marked adults using fluorescent powders only were made; two at each of the three culvert locations. Single release points were at each end of the valley, and another approximately in the center. Three powder colors were used, one for each release site. The mosquitoes for release were collected by aspiration from congregating sites in Yolo, Placer, and Sutter Counties. Very hot weather resulted in a high mortality of adults during a holding period of a week and in transit to the release points on September 22 and 23. The surviving mosquitoes, however, appeared normally vigorous, were dusted in covered screened cages and released within about 15 minutes in the center of the culvert. None immediately flew out of these resting sites and very few attempted to bite the authors. During September and October moderate north winds, 5-10 mph, occurred on September 1, October 16, 27, and 29. Between September 17 and 21 a very severe north wind prevailed, varying from seven to in excess of 20 mph. No strong winds were recorded during or shortly following the releases. A listing of the releases (all females) and recaptures with pertinent data is presented in Table 5.

A total of 4800 marked specimens were released and 5190 "wild" mosquitoes captured between September 22, 1964 and March 18, 1965. During this period 383 collections were made from 31 stations with an average of 13.6 mosquitoes per collection. The detailed collections are presented in Table 6.

Two marked mosquitoes were recaptured; one south of the center of the valley, 5.75 miles SSE of the central release point, and one 17.5 miles SSE of the northern release point and east of the valley. An additional three specimens were recaptured at their release sites; one at the central site and two at the southern location. No recaptures were made in the northern part of the valley. As two releases were made at each site two to three weeks apart, and using only one color per site, the exact number of days intervening between releases and recapture cannot be determined for all of the recaptures as most occurred after the second release. One specimen was recovered 20 days after release at the southern release site, three 28 or 63 days later and one (February 18), 121 or 142 days after the releases of September 29 and October 20, respectively. The collecting stations were largely farm buildings and culverts, the less productive not being visited regularly. The entire valley area was sampled by means of all accessible roads; the stations used thus represented all sections. In the northern half of the valley the average per collection of 14 stations was 6.6 mosquitoes (absolute range, 0-72) while in the southern 14 stations the average was 13.8 (absolute range, 0-400) or twice as many. The three stations east of the valley proper (in one of which a recapture was made) had an average of 8.6 mosquitoes per collection. Collections were continued until all overwintering adults had disappeared.

The pertinent findings from this experiment were: (1) small valleys adjacent to or opening into the Sacramento Valley are invaded in the fall by prehibernating *A. freeborni* originating from the summer breeding areas to the east and/or north; (2) the general fall movement of the migrating mosquitoes is in a southerly direction in this valley; (3) the maximum known distance a marked mosquito travelled from north to south within the valley was 17.5 miles in a period of four to five months; (4) many mosquitoes move about during the winter and sometimes return to a favored resting site as long as three to nine weeks later; and (5) the pseudo-dormant period of this mosquito extends over a maximum period of six months.

Third experiment, 1965-66. The fall flight experiment on this occasion was conducted in the large rice-growing district of western Placer County east of the Sacramento River (Fig. 1). This county is without a mosquito abatement district. It was the objective of this experiment to determine the fall flight pattern inside the bounds of a rice farming area. Within a five mile radius of the release point the elevation varies from 60 to 200 feet from west to east. This area is traversed by three streams, two of which flow all year westward from the Sierra Nevada foothills. The wind pattern is fundamentally the same as on the west side of the river, i.e., a prevailing SSW wind and strong, irregular NNW-NW winds in the fall. The release point was four miles west of the small town of Lincoln at the roadside beneath a willow tree. A nearby culvert, full of water nearly all year, served as a drainage ditch from adjacent rice fields. This site, intentionally, did not provide a good congregating or overwintering niche. Mosquitoes released at this point were expected to disperse quickly. The mosquitoes for marking were collected from congregating areas in Yolo, Sutter and Placer counties and held from one to six days in the dusting cages with water only. Six releases, totaling 30,500 mosquitoes, were made using three different colored dusts for marking (see Table 7). As they were released many of the mosquitoes alighted temporarily in the grass and weeds, some drifted southward with a slight breeze and a few flew into the narrow space above the waterline in the culvert. No attempt was made to recapture or observe any remaining mosquitoes at the release site at a later time. No buildings were closer than an eighth of a mile, and no marked specimens were recaptured at this closest residence.

Several hundred potential collecting stations within a ten mile radius of the release point were inspected to select the most favorable, i.e., those offering adequate winter protection with warm-blooded hosts nearby. These include all types of farm buildings, animal shelters, cattle feed lots, turkey hatching and feeding houses, basements, culverts, bridges, abandoned cabins, school bus waiting stations, old vaults, wine cellars, etc. This farming area has many hundreds, even thousands of mosquito winter hibernating niches. The limitation of weekly collections, each of which had to aspirated by the authors, made it necessary to select the most productive stations which might increase the chances of recapture. We realized that with such a very great wild population as was present, and with innumerable resting sites, that the dilution of the 30,500 marked mosquitoes was extreme and the odds against recapture were very high. A recapitulation of releases and recaptures is given in Table 7.

A total of 40,580 "wild" mosquitoes were aspirated in 365 collections at 49 different locations situated from one-eighth to 11 miles from the release point from September 16, 1965 through March 29, 1966. The average number of mosquitoes per collection during this period was 111.2. The details of these collections are given in Table 8. For three days following the

Table 6. Adult *Anopheles freeborni* collections in flight range experiment 2. Capay Valley, Yolo County, California. 1964-65.

Date		♂♂	♀♀	Total	No. Stations Collected	Ave. No. Mosq. per Station
Sept.	22	32	627	659	11	59.9
	29	35	834	869	17	51.1
Oct.	6	13	328	341	13	26.2
	13	1	304	305	17	17.9
	20	0	197	197	14	14.0
	27	2	319	321	15	21.4
Nov.	3	0	428	428	18	23.7
	10	1	326*	327	14	23.3
	17	0	220	220	14	17.3
	24	0	173	173	16	10.8
Dec.	1	0	191	191	18	10.6
	8	0	148	148	16	9.2
	15	0	163	163	20	8.1
	29	0	266	266	11	24.2
Jan.	5	0	68	68	11	6.2
	12	0	91	91	14	6.5
	19	0	114	114	14	8.1
	26	0	72	72	14	5.1
Feb.	4	0	61	61	15	4.1
	11	0	60	60	16	3.8
	18	0	63*	63	17	3.7
	25	0	40	40	18	2.2
Mar.	4	0	8	8	18	0.4
	11	0	7	7	18	0.4
	18	0	0	0	14	0.0
		84	5108	5192	383	13.6

*Marked specimens recaptured.

Table 7. Summary of releases and recaptures of marked *Anopheles freeborni* adults. Flight range experiment 3. Placer County, California. 1965-66.

Date	Estimated no. released		Conditions			Marking dust color	Recaptures			
							No.		Days after release	Distance and direction from release point (miles)
	Males	Total	Temp. (°F.)	Time (am)	Wind (mph)		♂	♀		
Sept. 14	20	8,500	79	11:15	1-2,N					
						Blue	1		2-9	1.5 W
Sept. 21	18	6,000	74	11:00	>1,S					
Sept. 28	0	5,500	64	11:20	1-2,N					
						Pink		1	9-16	0.87S
Oct. 5	35	3,500	68	11:20	1-2,S					
							1		2-9	0.87S
Oct. 12	16	3,150	71.5	11:15	>1,S			1	2-9	0.87E
						Gold		1	2-9	3.0 SE
Oct. 19	120	3,850	66	11:00	3-5,N			1	21-28	3.0 SE
								1	91-98	3.25NE
Total	209	30,500					2	5		

Table 8. Adult *Anopheles freeborni* collections in flight range experiment 3. Placer County, California. 1965-66.

Date		♂♂	♀♀	Total	No. Stations Collected	Ave. No. Mosq. per Station
Sept.	16	65	120	185	10	18.5
	23	207*	628	835	17	49.1
	30	377	881	1258	16	78.6
Oct.	7	493	1109	1602	19	84.3
	14	204	724*	928	18	51.6
	21	271*	1637*	1908	20	95.4
	26	143	1769	1912	16	119.5
Nov.	2	59	1975	2034	15	135.6
	9	77	2602	2679	18	148.8
	16	6	2285	2291	11	208.3
	23	1	1754	1755	13	135.0
	30	0	4205	4205	16	262.8
Dec.	7	0	2859	2859	13	220.0
	14	0	1520	1520	13	116.9
Jan.	6	0	1049	1049	13	80.7
	11	0	1573	1573	12	131.1
	18	0	1751*	1751	15	116.7
	25	0	1045	1045	11	95.0
	31	0	2067	2067	13	159.0
Feb.	8	0	1467	1467	12	122.3
	15	0	1377	1377	13	105.9
	21	0	774	774	12	64.5
Mar.	1	0	1645	1645	14	117.5
	8	0	1142	1142	13	87.8
	17	0	625	625	10	62.5
	29	0	101	101	12	8.4
		1903	38684	40587	365	111.2

*Marked specimens recaptured.

first release a severe north wind blew. Moderate northwest winds blew September 25, 28, and October 15. It is interesting to note that at the time the last release was made (October 19) a 3-5 mph north wind was blowing. Of the seven recoveries, five were from this release.

In an attempt to analyze the effect of the north winds on the general movement or fall population shift we have rearranged the collection data by quadrants in relation to this ecological factor. The following pertinent collection data supplements Table 9:

	Upwind	Downwind	NE Crosswind	SW Crosswind
No. stations	11	19	12	7
Times Collected	83	149	90	43
Avg. no. mosquitoes per collection	105	131	92	93
No. marked mosquitoes recaptured	1	4	1	1

It was not possible to find an equal number of good resting sites in each quadrant. However, we feel sufficient stations were collected, as evidenced by the large numbers taken, to adequately sample the area and show the general movement of the overwintering population. The greatest accumulation of mosquitoes in the stations was in November and in the downwind direction. This is reflected also by the recapture of four of the seven marked specimens in the downwind quadrant in October and November. The second largest movement of the population occurred in January (Table 9) and was upwind and to the northeast. We have not atempted to correlate in any detail this shift with a rise in temperature or prevailing south winds which occur at this season. However, during this period of increased catches we recaptured the only (and the last) marked mosquito in the northeast quadrant (Fig. 1) following a rise in the daily maximum temperature (Marysville) to 68°F on January 16.

Six additional collecting stations in Sacramento County varying from 13 to 19.25 miles to the south of the release point were established. These were collected from October 21, 1965 to March 31, 1966 by

Table 9. Adult *Anopheles freeborni* collections in flight range experiment 4, arranged in quadrants in relation to the north wind. Placer County, California. 1965-66.

Month	No. collections	All Stations Total	All Stations Avg. per collection	Upwind Total	Upwind Avg. per collection	Downwind Total	Downwind Avg. per collection	NE Crosswind Total	NE Crosswind Avg. per collection	SW Crosswind Total	SW Crosswind Avg. per collection
Sept.	43	2314	63	321	36	1396	87	306	51	255	43
Oct.	73	6350	86	1490	99	3039	87	854	61	967	108
Nov.	73	12812	176	2093	110	7024	270	2443	122	1362	170
Dec.	26	4319	166	879	176	2720	227	509	73	271	136
Jan.	64	7374	115	2014	144	2526	101	2199	137	746	83
Feb.	37	3588	97	951	119	1530	96	910	114	227	45
March	49	3593	80	951	73	1309	69	1075	83	178	45
	365	40587	111	8741	105	19544	131	8296	92	4006	93

personnel of the Sacramento – Yolo County Mosquito Abatement District. A total of 2827 *A. freeborni* were identified and examined under ultra violet light by us. No marked specimens were found. Also, to the east of Lincoln in the foothills three stations were established, 10.5, 12 and 14.5 miles from the release point (See Table 2.) No marked mosquitoes were taken from this area.

Data from this 1965-66 experiment enable us to draw the following conclusions: (1) fall dispersal within an uncontrolled rice mosquito breeding area appears to be in all directions (Fig. 1); (2) the major movement of the population was generally in a southerly direction; (3) the population reached a peak in shelters in November; (4) with many ideal overwintering niches available nearby, it is not necessary for the prehibernating phase to migrate great distances to find suitable shelters; (5) the large number of males collected (Table 8) indicates extensive local breeding.

In such an area supporting a very large population, it is necessary to release many times more marked individuals than the numbers of wild mosquitoes that can be collected to assure a high recapture rate.

Fourth experiment, 1966-67. In 1945 Rosenstiel (1947) studied the dispersion of *A. freeborni* in the Yuba City area. Four "zones" were established and seven stations about one mile apart in an east-west line from the Yuba River to the junction of the Tisdale and Sutter Bypasses, or approximately along O'Banion Road, were sampled. This worker recorded the number and condition of the mosquitoes at each site but did not remove or dissect them. These stations were collected nine times during September and October only. No consideration was given to the wind as a factor aiding the dispersal. His counts showed a peak of adults in the rice field station the third week in August and a peak one month later 4 to 4.5 miles to the east.

Table 10. Summary of releases and recaptures of marked *Anopheles freeborni* adults. Flight range experiment 4. Sutter - Colusa area, California. 1966-67.

Date	Estimated No. released ♂	Estimated No. released Total	Conditions Temp. (°F)	Conditions Wind (mph)	Conditions Time (a.m.)	Marking Dust Color	Marking Dust Type	Recaptures No. ♂	Recaptures No. ♀	Recaptures Days after release	Recaptures Distance and direction from release point (miles)
Oct. 10	35	400	68	0	9:45	Green Gold	Metallic Fluorescent	0	0		
Oct. 12	270	6000	68	2-3,N	9:30	Red	Metallic	0	1	13	3.75W
						Pink	Fluorescent	0	1	15	2.75S
Oct. 25	0	2600	77	0	11:30	Green	Fluorescent	0	1	14	2.25WNW
									1	97	0.6 S
									1	111	2.25WNW
Nov. 1	0	4300 700[1]	67	0	11:30	Blue	Fluorescent	0	0		

[1]Resting under bridge at time of release and dusted in place.

Table 11. Adult *Anopheles freeborni* collections in flight range experiment 4. Sutter - Colusa area, California. 1966-67

Date		♂♂	♀♀	Total	No. Collections	Avg. Per Collection
Oct.	13	107	1445	1552	7	221.7
	17	43	828	871	4	217.7
	18	91	3108	3199	9	355.4
	20	17	615	632	7	90.2
	25*	74	582	656	6	109.3
	27*	27	704	731	9	81.2
Nov.	1	13	1430	1443	4	360.8
	3	7	838	845	6	140.8
	8*	2	2751	2753	9	305.9
	10	7	828	835	6	139.2
	15	6	2166	2172	9	241.3
	22	2	3976	3978	12	331.5
	29	0	1445	1445	8	180.6
Dec.	7	0	3615	3615	11	328.6
	13	0	3502	3502	12	291.8
	20	0	2351	2351	10	235.1
	27	0	1808	1808	11	164.4
Jan.	4	0	1896	1896	9	210.7
	11	0	1735	1735	10	173.5
	17	0	1103	1103	11	100.3
	25	0	1255	1255	9	139.4
	31*	0	1333	1333	10	133.3
Feb.	8	0	713	713	11	64.8
	14*	0	409	409	10	40.9
	21	0	604	604	11	54.9
	28	0	578	578	11	52.5
Mar.	7	0	97	97	9	10.8
	14	0	68	68	9	7.6
	21	0	30	30	4	7.5
		396	41,813	42,209	254	166.2

*Marked specimens recaptured these dates.

With Rosenstiel's work as a background, we planned the fourth experiment in the *A. freeborni* flight range program. Between the Yuba-Sutter and Colusa Mosquito Abatement Districts on State Highway 20 there is an area about 15 miles wide which has had little or no control. From the center of this strip, at which point we established our release site, the uncontrolled area extends 15 miles south to the Yolo County line and approximately the same distance into the Federal waterfowl management area of Butte County to the north. The main objective of this experiment was to demonstrate the pattern of fall dispersal from a known major, highly attractive, congregating and hibernating site near the center of the rice growing section of the valley.

The principal release point chosen is the best congregation area we have found yet in the Sacramento Valley. In years of high population we have estimated 100,000 *freeborni* resting under this old highway bridge, which is located adjacent to the present highway and four miles east of the community of Meridian. This site on the Sutter Bypass offers the maximum of protection for mosquitoes, as well as freedom of dispersal if they so desire. The Butte Sink lies to the north, and a considerable inaccessible mountainous area (Marysville Buttes) extending up to 2117 feet is to the north and northeast. Innumerable but much more widely spaced farms (a large number of which produce many hundreds of acres of rice) and resting sites are present to the south (Fig. 2) than are found in Placer County. The Sacramento River meanders in a south-southeast direction through the area.

Mosquitoes for marking were aspirated in congregating sites in Yolo, Colusa, and Placer Counties and held for a maximum of one week with water only. Three releases were made at the major release site and, additionally, one small lot (400) was freed on the porch of an old stone house in the northwest corner of the community of Sutter. This latter location is 4.5 miles to the northeast of the main site and is in an orchard district. A total of 14,000 mosquitoes were marked and the data of the releases and recaptures are given in Table 10. During the period from October 13, 1966 to March 21, 1967, 42,184 "wild" specimens were taken from a total of 254 collections. The average number of mosquitoes per collection was 166.1. The detailed counts are listed in Table 11. Strong north winds occurred on October 13 and 16 and on November 7-9. Five marked female mosquitoes were recaptured from the three major releases; three from the release of October 25. No specimens were recaptured from the small release in Sutter.

In addition our colleague, Dr. Robert K. Washino, made 24 mosquito collections from this area between

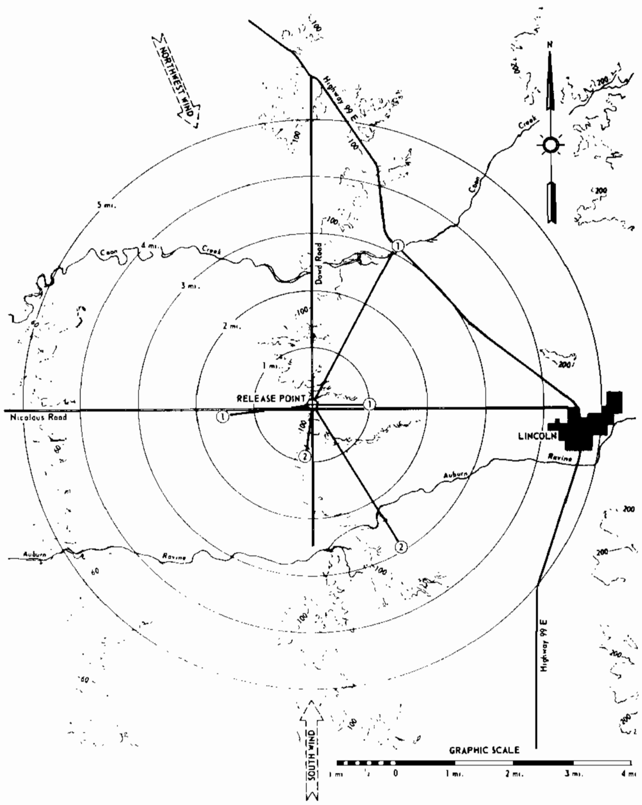

Figure 1 — Pattern of dispersal of *Anopheles freeborni* in realease-recapture experiment Number 3, September 16, 1965 to March 29, 1966, Placer County, Calif.

Table 12. Summary of release-recapture experiments with marked *Anopheles freeborni* adults during the fall flight. Lower Sacramento Valley and vicinity, California. 1963-67.

Year	No. sites utilized	No. releases	Approx. No. marked mosquitoes released: ♂♂	Total	RECAPTURES: No. ♂♂	♀♀	Distance from release point (miles)	Direction	Days after release	Per cent recovery
1963-64	1	1	Unknown	4,000		1	0.87	W	29	
						3	1.75	W	29	0.10
	1	1	Unknown	1,500		0				0
1964-65	1	2	0	1,400		1	17.5	SSE	121-142	0.08
	1	2	0	2,000		1	5.75	SSE	35-49	0.05
	1	2	0	1,400		0				0
1965-66	1	2	38	14,500	1	0	1.5	W	2-9	0.0006
		2	35	9,000	0	1	0.87	S	9-16	0.01
		2	136	7,000	1	0	0.87	S	2-9	
						1	0.87	E	2-9	
						1	3.0	SE	2-9	
						1	3.0	SE	21-28	
						1	3.25	NE	91-98	0.07
1966-67	1	1	35	400	0	0				0
	1	1	270	6,000	0	1	3.75	W	13	
						1	2.75	S	15	0.03
		1	0	2,600	0	2	2.25	WNW	14-111	0.03
						1	0.6	S	97	0.11
		1	0	5,000	0	0				0
	8	18	514	54,800	2	16	3.05 (mean)			0.032

Table 13. Chronological summary of recaptured marked *Anopheles freeborni* adults[1] in flight range study. Lower Sacramento Valley and vicinity, California. 1963-67.

	September			October			November			December			January			February			March		
	♂	♀	Day of month	♂	♀	Day of month	♂	♀	Day of month	♂	♀	Day of month	♂	♀	Day of month	♂	♀	Day of month	♂	♀	Day of month
1963-64							0	4	12												
1964-65							0	1	10							0	1	18			
1965-66	1	0	23	0	1	14	0	1	9				0	1	18						
				1	2	21															
1966-67				0	1	25	0	1	8												
				0	1	27							0	1	31	0	1	14			
	1			1	5			7			0			2			2			0	

[1]All marked specimens observed or collected at the release points omitted from table. Additional marked specimens were recaptured at the release points as follows:

	Release point		
1963-64	1	-	78
	2	-	194
1964-65	No.	-	0
	Central	-	1
	So.	-	2
1965-66	1		0
1966-67	1		35
	2		0
			310

Figure 2 — Sutter Basin area south of Buttes. Release-recapture experiment number 4 with marked *Anopheles freeborni* was conducted in this area, 1966-67.

Table 14. Condensed summary of *Anopheles freeborni* flight range experiments

Year	Collecting Period	No. Coll. Stations	No. Times Coll.	No. unmarked spcms. Coll.	Avg. No. mosquitoes per coll.	Location
1963-64	Oct. 17 - Mar. 19	9	59	1731	29.3	W. Colusa County foothills
1964-65	Sept. 22 - Mar. 18	31	383	5190	13.6	W. Yolo County foothill valley
1965-66	Sept. 16 - Mar. 29	49	365	40580	111.2	E. Sacramento Valley rice district
1966-67	Oct. 13 - Mar. 21	49	254	42184	166.1	Central Sacramento valley rice district

October 11, 1965 and March 15, 1966, totaling 563 *A. freeborni*. One hundred and ninety-three specimens were from the Sutter release point. No marked mosquitoes were among his collections.

The conclusions to be drawn from this fourth and last experiment are similar to those of the previous year, namely.: (1) dispersion from a given point in the rice-growing area in the Sacramento Valley is not always in one direction, but random (In this case the recaptures were made in an arc of 100 degrees, 2.75 miles south to 3.75 miles west to 3.25 miles west northwest of the release point.); (2) the majority of the recaptures (3 of 5) were made in October; (3) the greatest concentration of mosquitoes appears to be at the margins of large, open rice acreages and in semi-open protected shelters; (4) dispersal out of well-protected areas is not extensive; (5) the population over-wintering in this part of the valley is very great and the highest concentration of dormant mosquitoes is found in November. Local surface wind currents are very variable and influenced by hills, channels, levees, and wooded areas. Such conditions probably account for this pattern of recaptures south of the Buttes. Particularly significant among the recaptures was the collection of two well-marked normal females, one blooded-gravid and one empty, at the release site February 21, 1967, or 125 days after release.

Aside from the four experiments discussed above, another type of dispersal experiment was attempted at Point Reyes Station, Marin County. No *freeborni* larvae ever have been collected in this district. On May 14, 1966, 402 unmarked, laboratory-reared *freeborni* adults, 239 females and 163 males, were taken from Davis to this coastal community. Many of the females were blooded. They were released in an open basement of an abandoned house adjacent to a farm pond where *Anopheles franciscanus, occidentalis,* and *punctipennis* larvae were collected regularly. After release at 11:15 a.m., the mosquitoes came to rest on the walls and subfloor. At the time of release it was sunny, warm, (78°F.) and no wind. For five months following this release adult and larval collections were made at this pond and several additional nearby locations. No *freeborni* were found. Again, on September 27, 1966, 700 females, collected in the field in Yolo County, were released at the same site. None were visibly blooded or gravid. These mosquitoes were dusted with a red metallic powder. The conditions at release were a 5 mph northwest wind and a temperature of 76°F in the basement release site (81° outside, sunny and dry). Two weeks later, October 11, one marked female (non-blooded or gravid) was recaptured 0.75 miles south of the release point in a culvert. The temperature at the resting site of the recapture was 62°F. No additional specimens of *freeborni* were found. The per cent recovery, therefore, was 0.14. This rather limited test indicates that this mosquito cannot, or only with great difficulty, become established in this coastal area. Also, that adult mosquitoes in the area have a tendency to be carried inland (in this case downwind) by the prevailing breeze off the water.

CONCLUSIONS

We now believe this mosquito has four "phases" (incorporating in part the early terminology of Freeborn and Rosentiel) during its annual cycle:

Phase I. Summer phase: non-migratory, reproducing chiefly in rice fields, farm ponds and ditches.

Phase II. Fall migratory phase: divided into (a) congregations in large open shelters near breeding areas in late August and early September and (b) migratory or dispersal period in late September and October.

Phase III. Winter "hibernating" phase: found in November to early March. During this period, in cold weather particularly, the mosquitoes are quiescent, often flattened out in small, protected niches free from wind, rain, and frost formation. During warm periods movement takes place from shelter to shelter locally with little or no blooding.

Phase IV. Spring dispersal phase. This flight period of the surviving (mated) females is to seek blood. In late January this activity becomes quite noticeable around the home and farm yard. The remaining over-wintering "stragglers" usually disappear by mid-March. Following this spring blood meal, migration appears limited to local water sources for oviposition.

Summary of the flight range study. We summarize herewith four years of flight range studies with 18 release-recapture experiments totaling 54,800 marked mosquitoes (with a 0.032 per cent recovery, see table 12) in the lower Sacramento Valley:

Dispersal from major rice breeding areas is in all directions with a larger percentage of the population

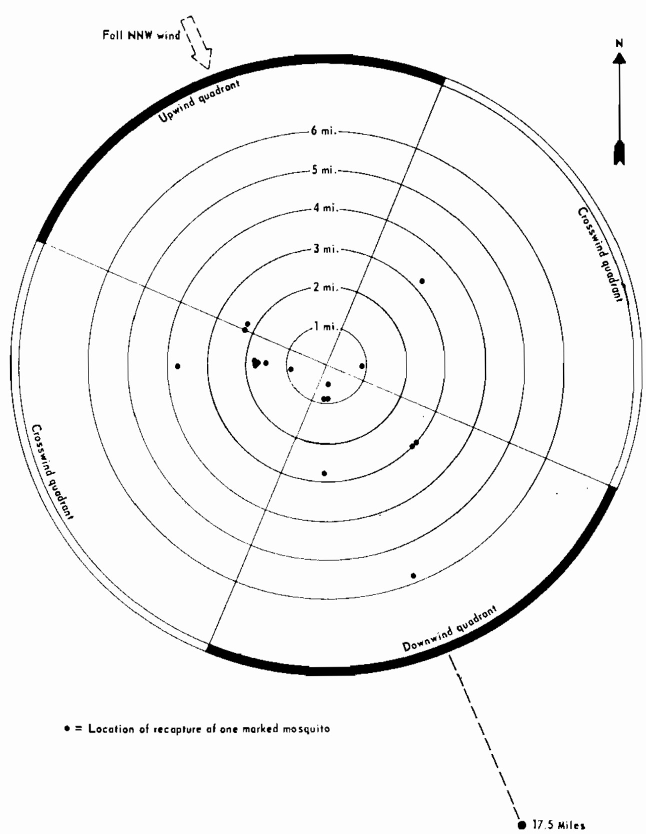

Figure 3 — Composite diagram of 18 releases with marked *Anopheles freeborni* in the lower Sacramento Valley, 1963-67, showing direction and distance of the recaptures during fall and winter.

moving more generally in a southerly direction than northward or laterally.

The irregularly occurring, fall north winds appear to play some part in the flight of this mosquito, but in periods of little or no wind large numbers filter into local communities from nearby rural areas.

The time of the major fall flight into residential areas varies from year to year, but is usually in late September. By late October infiltration throughout a community has taken place. The maximum numbers in the collecting stations were taken in November.

Flights as far as 17.5 miles do occur on the part of some individuals; however, we feel the great majority of mosquitoes seek, and do find adequate overwintering quarters within five miles of their breeding site in most farming areas.

The mean distance of the 18 recaptured marked mosquitoes away from the release points was 3.05 miles. Large numbers of marked mosquitoes (310) did not leave the release point or its immediate vicinity.

The majority of marked specimens were recaptured in the rice area during October; at the release sites only in cold weather in December, and again in much smaller numbers after the middle of January during the spring movement (Table 13).

Movement of the "prehibernation" population into the foothills at the margins of the valley definitely takes place to at least 10 miles, and abundantly up to about 400 feet elevation. The numbers overwintering in the valley are many times greater than in the foothills (Table 14).

The males also migrate into the foothills (up to six miles) at the margins of the Sacramento Valley, but to a very limited extent.

During the winter there is a continual "relocation" of the semidormant females from niche to niche, with the exception of periods of time when the temperature is below about 40-45°F.

The female of this mosquito commonly lives five months in the winter and occupies many different resting sites, often many miles from its point of origin.

The flight range study of *Anopheles freeborni* together with that previously published on the other major rice field mosquito, *Culex tarsalis*, completes this phase of the ecological study. The results point up the fact that these mosquitoes fly great distances, the flight patterns being different in the summer than in the fall, making control in the rice growing areas of the state difficult particularly when organized along "political" boundaries.

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FIELD DEVELOPMENTAL STUDIES ON *CULEX PIPIENS QUINQUEFASCIATUS* REARED IN NATURAL, DAIRY BARN WASH AND SEWAGE EFFLUENT WATERS

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ABSTRACT

Field studies were conducted near Riverside, California from April through October, 1966, to determine the developmental rate of *Culex quinquefasciatus* when reared in natural (ground water), dairy barn wash and sewage effluent waters. Rearing chambers, with 50 first instar larvae, were placed in each source type every 28 days and observed for mortality, immature development and adult emergence. Maximum-minimum water temperatures were taken daily at each station. The highest per cent mortality occurred in larvae reared in natural or ground water; a minimum developmental period of eleven days at a mean daily water temperature of 74-78° F was observed. The lowest percent mortality occurred in the dairy barn wash water, in which the minimum developmental period was eight days at a mean daily water temperature of 79-82°F. *Cluex quinquefasciatus* reared in sewage effluent developed in the shortest period, seven days, at a mean daily water temperature of 84°F.

SURVEILLANCE OF *AEDES AEGYPTI* IN THE U.S. AIR FORCE

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The Department of Defense, in agreement with the Department of Health, Education and Welfare shares in the eradication of *Aedes aegypti* by assuming responsibility for the control of this medically important species on all its installations within the presumed infested zone. The Department of Defense in 1965 delegated responsibility for this control to the three military departments and directed them to proceed according to their respective, existing pest control programs. The Department of the Air Force, early in 1965 appointed project officers in the major air commands and designated the Civil Engineer of the commands and subordinate bases to initiate a detailed control program to be considered a separate effort within the pest control responsibility of each air base. Surveys to determine the location and extent of mosquito breeding remained the responsibility of the medical service. Measures required to supplement the present mosquito control programs are performed in accordance with procedures of the U.S. Public Health Service. The application of pesticides is accomplished by personnel trained and certified under existing Air Force provisions. Active eradication programs are now in operation on bases in Texas and Florida and in some bases in Alabama, Georgia and Mississippi. These are coordinated with comparable efforts of state and federal public health agencies in adjacent off-base areas.

The USAF Epidemiological Laboratory located in San Antonio, Texas, is the sole consultant reference source for medical entomology and disease vector control for the Air Force in the 49 continental states, Greenland, and the Caribbean. The identification of arthropods from air bases is a part of this consultant service and this element was also included within the eradication program. In the latter part of 1965 the USAF Epidemiological Laboratory was requested by Headquarters, U.S. Air Force, to supervise the entire survey effort of the program within the Air Force and, if necessary, to perform actual surveys on bases not possessing the capability to perform such effort.

The U.S. Air Force has 42 bases, belonging to 9 major air commands in N. Carolina, S. Carolina, Tennessee, Georgia, Mississippi, Louisiana, Arkansas, Alabama, Florida, Texas, Oklahoma, and Puerto Rico. These states and Puerto Rico have been designated by the U.S. Public Health Service as forming the area presumed to be infested with *Aedes aegypti.* Major commands of the Air Force are not geographically defined as are comparable commands of the Army and Navy. All army units in Florida belong to the Third Continental Army; however, the 7 Air Force bases in this one state are in 5 major air commands. Only three of the 9 air commands with bases in the infested area have headquarters in that area. In addition, the separate major air commands, unlike their counterparts in the other military services, have distinctly different missions and the subordinate bases reflect this disparity physically and operationally. It is therefore necessary to consider these differences when assisting in the solution of a large ecological problem extending across an entire region of the nation.

Entomologists from the USAF Epidemiological Laboratory visited 35 of the 42 bases in the *A. aegypti* receptive area during 1965-66. The visits included an evaluation of the local eradication capability. Local commands and medical and civil engineer personnel were contacted and briefed on all elements of the eradication program. The status of personnel, training, operations, pesticides and equipment was investigated. In addition the local state and federal public health agencies near each base were also visited in order to assure coordination of military programs with those of the local civilian agencies.

The USAF Epidemiological Laboratory identified, during 1965, 20,830 larval and adult mosquitoes from 17 bases in the infested zone. In 1966, 480 collections representing 28,852 specimens from 22 bases in the zone were received and identified. Except for one shipment of twelve larvae from Maxwell AFB, Alabama, on October 31, 1966 none of these collections included *A. aegypti.* All lavae from that single shipment were identified as *A. aegypti.* The only adult

A. aegypti ever received by this laboratory was forwarded from Cannon AFB, New Mexico, in 1962.

Absence of *A. aegypti* from mosquito collections sent by Air Force bases in the zone of potential infestation does not necessarily mean that those bases are free of infestation. Ramey AFB, located near Aquadilla, in the northwestern sector of Puerto Rico, was found re-infested this year after an initial attempt at eradication in 1965.

A special training course was given in 1965 to representatives of medical and civil engineering services from bases in Texas. This course was a joint endeavor of the training section of the *Aedes aegypti* Eradication Program, U.S. Public Health Service, and the USAF Epidemiological Laboratory, and was scheduled to coincide with the increased activity of the eradication program in southern Texas.

SEASONAL MOSQUITO DISTRIBUTION AND ABUNDANCE IN CENTRAL LUZON

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ABSTRACT

As part of a long-range program for the investigation of arbovirus epidemiology in the Philippines, a one-year comprehensive mosquito survey of Clark AB, in Central Luzon, was conducted. A number of related projects dealing with taxonomy, bionomics, insecticide resistance, equipment development and isolation of viruses were run consecutively, but separately. The number of specimens collected was 420,518. Sixty-two species were identified and five groups of mosquitoes are under study as possible new species. Ten of these 62 species have not been previously reported at Clark AB. However, a total of 84 species have now been reported from Clark AB, 22 of which were not taken in this survey. The greatest number of specimens were of the genus *Culex*. The greatest number of species were of the genus *Anopheles*. The hot, wet season produced the greatest number of specimens, but the cool, wet season produced the greatest number of species. Animal baited traps recovered the greatest number of specimens, but light traps recovered the greatest number of species. After the initial reconnaissance and by the first week of the survey, 44 species had been recovered, but all 62 species were not recovered until the 50th week of the survey. *C. tritaeniorhynchus summorosus* is probably the most important species on Clark AB. It ranked first in number of specimens taken overall and was first in three of the four seasons. It was second in the fourth season and, even though zoophillac, ranked second in human crepuscular landing collections. For virus isolation attempts, 23,621 specimens of *C. tritaeniorhynchus summorosus* were pooled. Smaller numbers of three other species were also pooled.

The following conclusions were drawn:

1. Because of pilferage, inadequate contract performance and the use of students as collectors, non-random gaps in data occurred. While statistical analysis was not possible, the results of the survey could be handled numerically, subject to the qualifications stated in the body of the paper.

2. Approximately 60-65 species of mosquitoes are present on Clark AB in any given year. However, there are marked changes from year to year in the composition of this group of species, probably as a result of variations in rainfall.

3. All common species and many rare species are recovered by the end of the first week of a survey. Rare species are recovered randomly during the entire period of a survey.

4. Because of climatic variation from year to year, surveys should last at least five years. However, this is operationally impossible, so we must be content with less than ideal information.

5. Investigation of the relationship between chance and microclimatology in discontinuous breeding and resting areas should be pursued. Some factor other than chance appears to be involved.

6. There is both a practical and theoretical necessity for using a broad range of collection methods in a survey.

7. Evn though a species is zoophilic, very large populations may pose a threat to man because the small fraction that bites man may be large numerically.

8. *C. tritaeniorhynchus summorosus* is the most important species of mosquito on Clark AB.

9. Satisfactory methods for pooling mosquitoes for virus isolation have been developed using a power aspirator for collection and a carbon dioxide stage for sorting.

Complete information on this study was published in EPIDEMIOLOGICAL LABORATORY TECHNICAL REPORT 15-16, December 1965. Fifth Epidemiological Flight, PACAF, APO San Francisco.

A STUDY ON THE EGG LAYING BEHAVIOR OF *AEDES AEGYPTI* IN CENTRAL TEXAS

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Abstract

Beginning in June, 1966, a study was initiated on the egg laying behavior of *Aedes aegypti* in Central Texas. The work was continued through November, 1966. An oviposition trap, developed by Fay and Perry, 1965, was used. This trap consisted of a hardboard paddle placed vertically in a black, tapered, pint jar, containing approximately one inch of water. The paddle served as the site of oviposition. Reagent grade ethyl acetate, suspended from the side of the jar in a two-dram vial, served as an attractant.

Six blocks were selected within an area known to be heavily infested with *Aedes aegypti*. A total of 24 ovitraps were placed on these blocks at the beginning of the study. The ethyl acetate attractant was withheld from 12 traps on three blocks. The difference in treatment was intended to furnish information on the

value of using ethyl acetate as an attractant. Water and ethyl acetate (where applicable) were added twice each week to each trap. At this time, a new paddle was placed in each trap; the exposed one was collected and microscopically examined for mosquito eggs.

Egg laying decreased during periods of little or no rainfall and increased when water was available for mosquito production. A definite reduction in egg laying was observed during cooler temperatures.

From results obtained in this study the ethyl acetate did not appear to increase the effectiveness of the traps.

A REPORT ON THE DISTRIBUTION AND BIOLOGY OF TREE HOLE MOSQUITOES IN THE WESTERN UNITED STATES

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Introduction

Published records of tree hole mosquitoes occurring in the western United States would indicate that such species are rare except in the Pacific Coast states of California, Washington and Oregon. In these states numerous records of *Aedes sierrensis* (Ludlow) exist and the species is often of pest importance.

In the monograph on the ecology of tree hole moquitoes by Jenkins and Carpenter (1946) only two species, *Aedes triseriatus* (Say) and *Aedes varipalpus* (Coq.) were reported from the entire western United States. *Aedes hendersoni* Cockerell was included but was considered a variety of *A. triseriatus.*

In 1955, Carpenter and LaCasse reported five species from the western United States that were known to inhabit rot cavities of trees. Since that time, however, a number of workers have contributed substantially to our knowledge of tree hole mosquitoes in the western United States, but the distribution of most species is still very inadequately known. At the present time eleven species are represented by apparently valid records. These species are: *Aedes hendersoni* Cockerell, *Aedes kompi* Vargas and Downs, *Aedes monticola* Belkin and McDonald, *Aedes muelleri* Dyar, *Aedes sierrensis* (Ludlow), *Aedes purpureipes* Aitkin, *Aedes varipalpus* (Coq.), *Anopheles barberi* (Coq.), *Orthopodomyia californica* Bohart, *Orthopodomyia kummi* Edwards, and *Orthopodomyia signifera* (Coq.). We did not collect *A. kompi*, *A. purpureipes* or *O. californica* during the present study. *Aedes kompi* was reported new for the United States by Burger (1965) and is known from only one locality in Santa Cruz County in southern Arizona. *Aedes purpureipes* also is apparently restricted to southern Arizona (McDonald, 1957). *Orthopodomyia californica* is known only from California (Chapman, 1964). The taxonomic status of the species in the genus *Orthopodomyia* in Arizona appears to be uncertain and we are not reporting on our collections in this genus at this time.

In the summer of 1964, we began a careful and systematic study of the tree hole habitat in the states of Arizona, Idaho, Montana, Utah, Wyoming and also made collections in southeastern Colorado, northeastern New Mexico and western South Dakota. The present paper is a report on six tree hole species belonging to the genera *Aedes* and *Anopheles.*

Their known distribution, based on published records and our own data are shown in Fig. 1.

All collections listed in this paper were made by the authors unless otherwise indicated. Most collections are new distributional records. Some records are from previously reported localities, but are included because the date of the collection is considered significant. Unless noted otherwise, all collections were larval from which associated adults were reared.

Species Reports:

Aedes hendersoni Cockerell

This species was originally described by Cockerell (1918) from adult females collected at Box Elder Creek, Wyoming. He considered it a variety of *Aedes triseriatus* (Say), differing from that species in having larger amounts of silvery scales on the dorsum of the thorax. Breland (1960) elevated *hendersoni* to full species rank on the basis of additional distinctive differences in larval characters. Published records of this species for the western United States prior to 1960 refer to *Aedes triseriatus.* These include Dyar (1917), one record, western Montana; Jenkins and Carpenter (1946), one additional record, eastern Montana; Harmston (1949), four records, eastern Colorado; Harmston and Rees (1946), one record, southwest Idaho; Rees and Harmston (1948), two records, central Wyoming. We have examined the Idaho and Wyoming and some of the Colorado specimens. They are all distinctively *hendersoni.*

Published records referred to as *hendersoni* are Breland (op. cit.), Boulder, Colorado; Harmston (1962), six records, northeastern Colorado; Nielsen, et al. (1963), three records, eastern Colorado, one record each, Idaho and Wyoming.

These records indicated a widely scattered, but sparse distribution for *hendersoni.*

During the summers of 1964, 1965, 1966, we collected intensively in the intermountain states. *Aedes hendersoni* was found to be very widely distributed. The species was present along every tributary of the Missouri River drainage system collected in Montana, Wyoming and western South Dakota. The same situation appears to be the case in eastern Colorado. The species is present west of the continental divide in western Montana where it has been found only

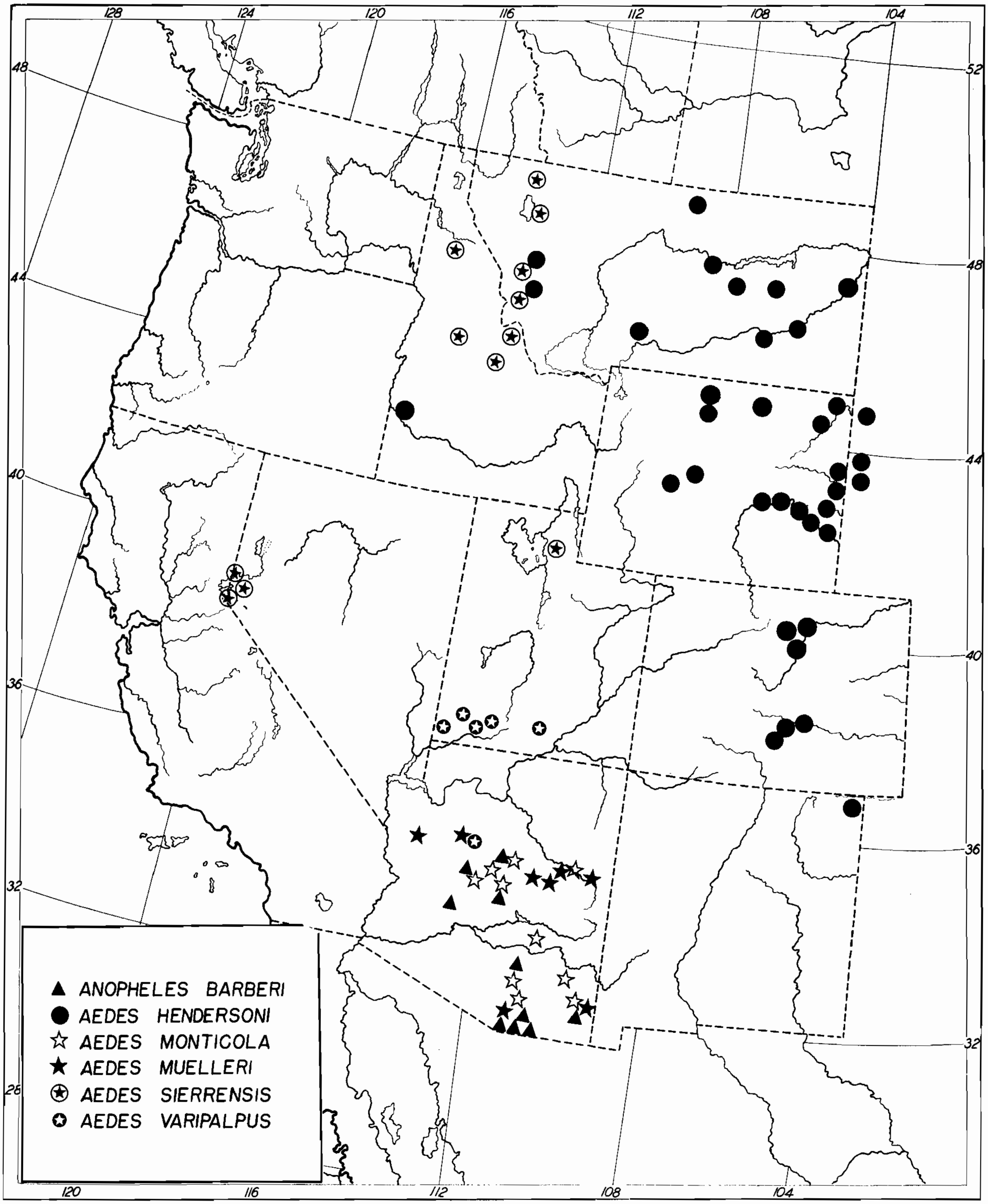

Figure 1–Known distribution of six tree hole species occurring in the inland western United States.

along the Bitterroot River between Hamilton and Missoula and at Nampa, Idaho, in the Snake River drainage. In the former locality it is common and often associated with *Aedes sierrensis*. In the latter region the species appears to be rare. We have intensively collected the Snake River drainage in Idaho and western Wyoming, but have been unable to find additional records of *hendersoni*. We have been unable to find this species in the Colorado River drainage of western Colorado and Utah. Despite an abundance of suitable tree hole habitats along this drainage no tree hole species were found until *Aedes varipalpus* appeared along some Colorado River tributaries in extreme southern Utah (See below).

Virtually all of our collections of *hendersoni* were in cottonwoods in close proximity to rivers. One collection in South Dakota was made in an elm tree hole.

We visited the type locality, Box Elder Creek in Wyoming, and found *hendersoni* larvae from which we reared adults.

No *Aedes triseriatus* were found in any of our collections. Both species are known to occur together in Texas (Breland, op. cit.) and in the midwest (Hedeen, 1963). Our data supports the belief of Breland that *hendersoni* is a species of the arid west and *triseriatus* is an eastern and southeastern species. The actual extent of the overlap in the ranges of these two species must still be determined.

Although *hendersoni* is common in many parts of the western United States, we do not believe the species to be of pest importance except in restricted areas. We collected biting females in a number of localities, but usually the females were shy biters and easily disturbed. In only one locality, James Kipp State Park in central Montana, did we observe biting females in appreciable numbers. Here during the collection period from 4:00-6:30 p.m. females were abundant and readily attacked. Biting was most severe after 6:00 p.m. Temperatures ranged from 75-78°F. At this locality we found a dry tree cavity containing a female white footed deer mouse, *peromyscus sp.* with several young. A considerable number of engorged *hendersoni* females were resting in this cavity, apparently having rceently fed upon the mice.

The development of *hendersoni* larvae appears to be quite rapid. First instar larvae collected in tree holes shortly after a heavy rain were reared to adults within two weeks at laboratory temperatures which ranged between 70-75°F. Scrapings from dry tree holes often contained eggs which hatched immediately when flooded with distilled water. The larvae were reared to adults in from two to three weeks at the same temperatures as noted above. Not all eggs hatch at the first flooding. Scrapings which had produced larvae when first flooded were dried out and reflooded. Eggs frequently hatched, but always in much smaller numbers. We were unable to get any additional hatchings with a third flooding.

Collection Records

COLORADO: *Pueblo Co.*, Vineland, Arkansas River, IX-4-66; Lime, St. Charles River, IX-18-66; 15 mi. So. Pueblo, Trib. St. Charles River, IX-18-66.

MONTANA: *Blaine Co.*, Zurick, VIII-15-64 A♀). *Custer Co.*, Miles City, 2371′, VIII-16-64. *Fergus Co.*, James Kipp State Pk., 2450′, VIII-15-64 (A♀, L.). *Garfield Co.*, Jordan, 2700′, VIII-16-64. *Missoula Co.*, Lolo, 3300′, VIII-5-65. *Park Co.*, Clyde Park, VIII-20-1919 (A♀) (A. Mail). *Petroleum Co.*, Hwy. 20 Mussel Shell River, 2600′, VIII-16-64. *Ravalli Co.*, Hamilton, 3520′, VIII-5-65. *Rosebud Co.*, Forsyth, 2650′, VIII-16-64.

NEW MEXICO: *Union Co.*, 21 mi. No. Clayton, No. Canadian River, IX-7-66.

SOUTH DAKOTA: *Butte Co.*, Belle Fourche, VII-13-66 (A♀, L.). *Custer Co.*, Hwy 79, Lame Johnson Cr., 3500′, VII-14-66 A♀, L.). *Fall River Co.*, Hwy 18/385, Cheyenne River, 3100′, VII-14-66.

WYOMING: *Bighorn Co.*, 3 mi. So. Manderson, 3900′, VII-12-66. *Converse Co.*, Box Elder Creek (Type Locality), 17 mi. W. Douglas, 5025′, VII-15-66; Orin Jct., 4700′, VII-15-66. *Crook Co.*, Devils Tower, VII-13-66; Moorcroft, 4200′, VII-13-66. *Fremont Co.*, 1 mi. E. Lander, 5357′, VII-12-66; Riverton, 5100′, VII-12-66. *Goshen Co.*, Lingle, 4165′, VII-15-66; Rawhide Cr., 14 mi. So. Jay Em, 4425′, VII-15-66. *Natrona Co.*, 5 mi. E. Casper, 5150′, VII-15-66. *Niobrara Co.*, Cheyenne River, Hwy 85, 3700′, VII-14-66; Old Woman Cr., Hwy 85, 3700′, VII-14-66. *Platte Co.*, Guernsey, 4354′, VII-15-66.

Aedes monticola Belkin and McDonald

This species was described by Belkin and McDonald (1957) from material collected in Madera Canyon, Santa Cruz County, in the Santa Rita Mountains of southern Arizona. Records were also given for Cochise, Graham, and Pima Counties.

We have found the species to be widely distributed over the southern half of the state east of Prescott.

We have taken larvae most often in rot cavities in the Arizona sycamore, but collections also were made in cottonwoods and live oak.

The species has been collected in pure cultures and associated with *Aedes muelleri, Anopheles barberi, Orthopodomyia kummi* and *Orthopodomyia signifera*.

Aedes monticola apparently is capable of overwintering in the larval stage. Fourth instar larvae were collected in late December both in Aravaipa Canyon, Pinal County, and in the type locality, Madera Canyon in the Santa Rita Mountains. In both localities the larvae were associated with *Anopheles barberi* and *Orthopodomyia* species; in Madera Canyon the species was *kummi*, in Aravaipa Canyon, another species, probably *signifera*.

Scrapings from a tree hole in Aravaipa Canyon were flooded and 1st instar larvae of *monticola* hatched shortly after immersion. At laboratory temperatures of 65-70°F the first adults emerged 23 days later.

No biting adults were collected in any of the following localities.

Collection Records

ARIZONA: *Coconino Co.*, Sedona, Oak Cr. Canyon, 4240′, III-19-66. *Gila Co.*, Globe, 3541′, III-22-66. *Navajo Co.*, Mortensen Wash, 14 mi. W. Show Low, 6300′, VIII-14-66. *Pima Co.*, Madera Canyon Rec. Area, 4800′, XII-26-66. *Pinal Co.*, Aravaipa Canyon, 11 mi. E. Hwy 77, 2600′, XII-21-66. *Yavapai Co.*, Oak Cr. at Chavez Crossing Campground, 3975′, III-20-66; Prescott, 5150′, III-19-66; Wet Beaver Cr. near Rimrock, 3700′, III-20-66.

Aedes muelleri Dyar

The larva of this species was unknown until described by McDonald (1957) from tree hole material collected in Madera Canyon in the Santa Rita Mountains of southern Arizona. McDonald summarized the known distribution which included three Mexican localities and four scattered localities in Arizona.

An additional record was reported from Brewster County, Texas, by Breland (1958).

We now report four additional records from the eastern part of central Arizona. All of our larvae were taken in tree holes in narrowleaf cottonwoods. The species was taken in pure culture and associated with *Aedes monticola* and *Orthopodomyia sp.*, probably *signifera.*

Based on available Arizona records the species seems to prefer the higher elevations. All of the Navajo County records were taken along the Mogollon Rim. No biting adults were collected.

Collection Records

ARIZONA: *Apache Co.*, Eager, 7100′, VIII-15-66. *Navajo Co.*, 2 mi. E. *Black Canyon* Lake, 7000′, VIII-14-66; Cottonwood Wash, 2 mi. W. Clay Springs, 6300′, VIII-14-66; Mortensen Wash, 14 mi. W. Show Low, 6300′, VIII-15-66.

Aedes sierrensis (Ludlow)

Most of the literature prior to 1957 refers to this Pacific Coast or Western Tree Hole species as *Aedes varipalpus* (Coq.). Belkin and McDonald (1956) reported that the type material of *varipalpus* was that of a species distinct from the Pacific Coast species. The name *sierrensis* was available as this name had been given by Ludlow to material which he had described from California in 1905. Ludlow's type material was determined to be the same as populations referred to as the Pacific Coast Tree Hole mosquito.

The true *varipalpus* now appears to be restricted to northern Arizona and southern Utah.

Aedes sierrensis is widely distributed and common in California, Oregon and Washington. Peyton (1956) reported that the Pacific Coast Tree Hole mosquito was known from 45 records in California, 14 records in Oregon and 10 records in Washington. In other localities the species is far less common. Stage et al. (1952) indicated a single record from Valley County, Idaho. Chapman (1961) reported *sierrensis* from four localities in eastern Nevada. Carpenter (1962) reported this species from northern Idaho and Nielsen *et al* (op. cit.) collected *sierrensis* in two localities in Flathead County, Montana.

During our study we found additional records of *sierrensis* in southwestern Montana, central Idaho, and northern Utah. The Montana and Idaho records are part of what we believe will be a continuous distributional pattern through the northwest to the Pacific Coast. The Utah records, however, are over 250 airline miles from the nearest Idaho records and despite intensive collecting we have found no evidence of this species occurring in-between these two areas. The Utah material then appears to represent either an accidental introduction or a relict population. The Utah collections are restricted to cottonwoods in a small section of the Weber River, covering a distance of less than five miles with the great majority of productive tree holes occurring at Riverdale, in a grove of cottonwoods, covering an area of only a few acres. Directly adjacent to this grove is a large railroad yard with much freight traffic from the Pacific Coast. These conditions supported the possibility of an accidental introduction from areas where *sierrensis* is abundant.

For the past two years we have continued to visit the Riverdale area at least twice monthly and have made a detailed study of the *sierrensis* population. During the winter of 1965-66, active larvae were present until the first part of February. Living larvae in all instars were often recovered in water under ice and did not disappear until the water in the holes froze solid. Larvae appeared again as soon as the winter ice melted. This occurred in mid-March. Thus, this species appears to be very well adapted to the severe winters that regularly occur in this locality. *Aedes sierrensis* is generally regarded as a severe biter on the Pacific Coast and often is of pest importance. The Utah population does not appear strongly inclined to take human blood. The study area contains at least a dozen productive tree holes including a large hole at the base of one cottonwood which usually harbors several hundred larvae at all times during the warmer seasons of the year. Despite this concentrated population we have rarely collected biting adults despite repeated visits at all times of the day and under the most favorable conditions.

It is our opinion now that it is most likely that the Riverdale material represents a well adapted relict population. Morphologically, however, we have been unable to find any significant differences between the Utah material and the other inland populations in Idaho and Montana or between any of these populations and comparative material from the Pacific Coast. Further study will be required to determine if the Utah population is subspecifically or specifically distinct.

Collection Records

IDAHO: *Custer Co.*, 10 mi. No. Challis, 5200′, VIII-4-65. *Lemhi Co.*, 1 mi. So. North Fork, 3900′, VIII-4-65 (A♀,L.).

MONTANA: *Missoula Co.*, Lolo, 3300′, VIII-5-65. *Ravalli Co.*, Hamilton, 3520′, VIII-13-64, VIII-5-65.

UTAH: *Weber Co.*, Riverdale, 4300′, IV-16-65; Uintah, 4400′, IV-28-66.

Aedes varipalpus (Coq.)

The true *varipalpus* was described by Coquillett (1902) from a single female collected at Williams in northern Arizona. Since that time most of the published references to this species have been in error and have referred either to *sierrensis* from the Pacific Coast or *monticola* from southern Arizona. The only valid records apparently are from two localities in northwestern Arizona (Belkin and McDonald, op. cit.) and one locality in southern Utah (Nielsen and Rees, 1959). The true *varipalpus* appears to be the rarest and most restricted in distribution of all of the species in the *varipalpus* complex. We have made intensive collections throughout Utah, but have found the species restricted to the extreme southern part of the state. Four new localities in southern Utah are reported here, all in the Colorado drainage. Collections in Utah have been taken from tree holes in

Fremont's cottonwoods and willows. Larvae apparently survive the winter in the southern Utah localities. Larvae of all instars have been collected in late December in sites where freezing temperatures never persist long enough to freeze the tree holes solidly.

Biting adults have been collected in most of the following localities.

Collection Records

UTAH: *Kane Co.*, Cottonwood Can., 5000', V-22-66, X-21-66; Orderville, 5460', V-7-65, XI-12-65, X-22-66. *Washington Co.*, Beaver Dam Wash, 4350', X-23-66; Zion Nat'l. Pk., 3950', XI-13-65; Leeds, 2750', IV-23-65, XII-31-65, III-17-66, XII-30-66.

Anopheles barberi Coq.

Although this species is common in the eastern half of the United States it is known only from Arizona in the western half. It was first reported by Richard, et al. (1956) from Santa Cruz County. Rigby et al. (1963) also reported the species from the same county.

We have found the species to be widely distributed over the southern half of Arizona east of Wickenburg.

The species is known to overwinter in the larval stage (Carpenter and LaCasse, op. cit.). We have found larvae of all instars in several localities in late December collections. At Wickenburg in several large willow tree holes hundreds of *barberi* larvae were present during the last week of December in 1965 and 1966. The water temperatures both years were bteween 46-49°F. When brought into the laboratory at temperatures of 65-70°F adults started emerging in three to four weeks. No biting adults were collected.

Collection Records

ARIZONA: *Cochise Co.*, Chiricahua National Monument, Monument Hqs., 5300', XII-24-66; Coronado Nat'l. Memorial, 5200', XII-25-66; 5 mi. W. Coronado Nat'l. Memorial, 5600', XII-25-66. *Maricopa Co.*, Hassayampa River, 5 mi. So. Wickenburg, 1800', XII-29-65, III-18-66, XII-19-66. *Pima Co.*, Madera Canyon Rec. Area, 4800', XII-26-66. *Pinal Co.*, Aravaipa Canyon, 11 mi. E. Hwy 77, 2600', XII-21-66. *Yavapai Co.*, Beaver Cr. Campground near Rimrock, 3680', III-20-66; Oak Cr., Chavez Crossing Campground, 3975', III-20-66; Prescott, 5150', III-19-66.

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EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON HATCHING OF EGGS AND ON LONGEVITY OF ADULTS OF *A. VEXANS* (MEIGEN)

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Abstract

Laboratory tests on hatching eggs of *Aedes vexans* showed that higher temperatures were required to hatch eggs of *A. vexans* than eggs of *A. abserratus*. *Aedes vexans* is a multivoltine species and appears about the middle of June in Manitoba while *A. abserratus*, a univoltine species, appears near the end of May. In the laboratory a hatch of 50% was obtained in *A. abserratus* at 10°C while the same percentage hatch occurred in *A. vexans* at 20°C. Eggs had been stored at 4°C and placed directly into hatching vials at different temperatures ranging from 2°-20°C.

In *A. vexans* the survival of embryos was much greater when eggs were stored for 5 months at 4°C than when they were stored for 5 months at 20°C. Hatching of viable eggs was also greater when eggs were stored at 4°C.

Eggs of *A. vexans* were able to withstand lower relative humidities when they were stored at 4°C than when they were stored at 15° or 20°C. At 4°C and 20% R.H. approximately 50% of the eggs survived for 3 weeks; at 20°C and 20% R.H. no eggs survived for more than one day.

Laboratory experiments on adults of *A. vexans* showed that adults were not adversely affected by a wide range of relative humidities provided they were given either water or honey to drink. Females lived from 3-4 weeks and males from 10-14 days on the average. Given no liquid to drink adults survived for only one to two days. Temperatures of 12°C and 21°C were both suitable for maintaining adults but no adults survived a temperature of 4°C for more than one day.

RELATIONSHIPS BETWEEN HOST ATTACK RATES AND CO_2-BAITED MALAISE TRAP CATCHES OF CERTAIN *SYMPHOROMYIA* SPECIES

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ABSTRACT

Five Malaise traps within a cross-shaped grid and another trap, located one-half mile away and near a group of penned, semi-tame deer, were operated in Mendocino County for 20 consecutive days beginning May 27, 1966. On 13 of these days host-seeking females were seen feeding on deer by an observer recording the number of flies feeding on several deer at 10 minute intervals from 0800 to 1700 P.S.T. During the same hours on these 13 days the six traps captured 3570 *S. sackeni* and 2353 members of the *S. pachyceras* complex.

CO_2 emission rates (about 2,000 ml/minute) were determined by the end of the day weight losses of styrofoam ice chests stocked with 15 pounds of dry ice per day. There was no significant difference in CO_2 emission levels between trap sites on given days, but there was great variation in the number of flies captured at different sites. The correlation between trap catches in the grid and the numbers of *S. sackeni* observed at hosts was 0.68 ($0.05>P>0.01$); that for the *S. pachyceras* complex was 0.88 ($0.001>P$). Correlations between fly catches in the lone trap near penned deer and the numbers of females observed on deer were 0.73 ($0.01>P>0.001$) for *S. sackeni* and 0.83 ($0.001>P$) for the *S. pachyceras* complex.

These high correlations and the almost identical correspondence between daily fluctuations in the total numbers of flies feeding on hosts and those caught in traps indicate that trap catches are as sensitive to changes in the day-to-day feeding populations as are observations on hosts. The above correlations also indicate that the traps were catching the same physiologically-defined portion of the population as were being attracted to hosts. These results show that it is possible to eliminate the many man hours necessarily involved in direct host observations and yet permit one, by use of CO_2-baited Malaise traps, to obtain comparable data on factors influencing attack rates, feeding cycles, parity rates, etc., as could be obtained by constant observation and collection of flies from hosts.

RELATIONSHIPS BETWEEN HOST ATTACK RATES AND CO_2-BAITED MALAISE TRAP CATCHES OF CERTAIN TABANID SPECIES

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ABSTRACT

The same CO_2-baited Malaise traps mentioned in the previous abstract captured 1100 specimens of 14 species of Tabanidae from May 27 to June 15, 1966. All trapping was conducted at the University of California Hopland Field Station located in the foothills of the Russian River Valley in Mendocine County. Trap catches were collected at 1100, 1400 and 1700 each day, and hourly weather data were obtained from the nearest field station weather station.

Seventy-eight per cent of the total trap catches were composed of four species: *Silvius notatus, Tabanus similis, T. kesseli* and *Apatolestes comastes* (in decreasing order). Air temperatures greatly influenced the numbers of flies caught in traps. The minimum host seeking activity threshold was approximately 70°F, whereas 80-89°F appeared to be the optimum host seeking temperature range for all but a few species. CO_2-baited Malaise traps caught significantly greater numbers of flies than unbaited traps. Unlike the results for the *Symphoromyia* species, many more tabanids were captured in the CO_2-baited traps than were observed on deer. Trap catches therefore revealed that more tabanids were present in the area than indicated by the numbers feeding on deer. These results suggest that the tabanids are less host specific than the *Symphoromyia* species captured, and that CO_2-baited traps may be more efficient in capturing hematophagous tabanids than in catching similar rhagionids. However, further studies are needed before such suggestions can be advanced as conclusions.

COMPARATIVE OVIPOSITION SELECTION PREFERENCE BY *AEDES DORSALIS* AND *AEDES NIGROMACULIS* TO THREE INORGANIC SALTS IN THE LABORATORY

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ABSTRACT

The effects of three inorganic salts on oviposition selection preference and egg hatching of *A. dorsalis*

and *A. nigromaculis* in Utah were studied. Both species exhibited selective preferences to increasing concentrations of sodium chloride and calcium chloride with *A. nigromaculis* more selective for the lower concentrations of both salts. Selective preferences were not evident to any extent when using potassium chloride as a selecting factor. Many of the eggs of both species when laid on the higher salt concentrations, failed to undergo the normal darkening process. The eggs of *A. dorsalis* were more resistant to this effect than were those of *A. nigromaculis*. When allowed to oviposit on soils moistened with a range of sodium chloride concentrations, the eggs of *A. dorsalis* were observed to hatch on concentrations as high as 4.1% NaCl while the eggs of *A. nigromaculis* were not observed to hatch on concentrations above 1.65% NaCL. Both oviposition selective preference and environmental effects upon the newly laid eggs appear to be important factors in limiting the larval habitats of these two mosquito species.

THE ANOPHELES (CELLIA) LEUCOSPHYRUS DONITZ 1901 GROUP IN THAILAND

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INTRODUCTION

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The distribution of members of the *Anopheles leucosphyrus* group was discussed in detail by Reid (1949) and by Colless (1956, 1957). These authors dealt chiefly with the forms found on the Malayan Peninsula and in Borneo, but Colless included distribution records for all known members of the group. This material was later summarized by Chow (1961) in a mimeographed publication of the World Health Organization for use by workers in the public health field, primarily because of the rapidly growing number of observations that one member of the group (*A. b. balabacensis* Baisas) is an important malaria vector in many areas of Southeast Asia. Extensive observations on *b. balabacensis* in Thailand were reported by Scanlon and Sandhinand (1965), who noted that records of the Royal Thai Ministry of Public Health indicated that two other members of the group, *balabacensis introlatus* Colless and *riparis macarthuri* Colless, had been found in southern Thailand near the Malayan border. Specimens of these were not available at the time, but additional collections by members of the Department of Medical Entomology, U.S. Army Medical Component, Southeast Asia Treaty Organization (SEATO) have shed further light on the distribution of members of the *leucosphyrus* group in Thailand, particularly in the Malayan border area. The term Malaya is used here to refer to the peninsular portion of the country now known as Malaysia. The larger political entity of Malaysia also includes the territories of Sabah, Brunei and Sarawak on the island of Borneo.

Interest in *A. balabacensis* and other members of the *leucosphyrus* group has also been heightened by the emergence of strains of *Plasmodium falciparum* which exhibit varying degrees of resistance to treatment by the most commonly used synthetic antimalarial drugs. In many of the areas of SE Asia where this phenomenon has been observed *balabacensis* is the most important vector. In addition, several members of the *leucosphyrus* group have been implicated as natural or laboratory vectors of simian malaria parasites, and recently Chin *et al.* (1965) reported on a naturally acquired human infection with the simian parasite, *P. knowlesi*, in a jungle area of Malaya.

The species discussed here are members of the Series *Neomyzomyia* Christophers, of the subgenus *Cellia* Theobald. Two other *Neomyzomyia* species are known from Thailand, *A. kochi* Dönitz and *A. tessellatus* Theobald. The members of the *leucosphyrus* group are all easily recognized by the presence of a broad white band covering the apex of the hind tibia and the base of the first hind tarsomere. No other *Anopheles* species in SE Asia exhibit this character. Identification of species and other forms within the group is far more difficult. A full discussion of relationships within the group and the probable evolutionary relationships among the forms may be found in Colless (1956). The species of the leucosphyrus group may be regarded as a series of sibling species in the sense of Mayr *et al* (1953) in which morphological distinctions are perhaps somewhat more readily made than is the case with members of the *Anopheles hyrcanus* (Pallas) species group in southeast Asia.

Unless otherwise stated all of the specimens discussed in this review are in the collections of the United States National Museum.

Anopheles balabacensis balabacensis BAISAS 1936

This is by far the most abundant and widely distributed member of the group in Thailand. Scanlon and Sandhinand (1965) noted that it had been reported from many localities in the country and continued collection by SEATO and Thai Ministry of Health personnel has reinforced this impression. *A. b. balabacensis* is somewhat secretive in its habits as regards adult resting and larval habitat, and it tends to be spotty in distribution even in what appear to be suitable areas. Furthermore, the females usually feed late at night and they may be missed unless night-

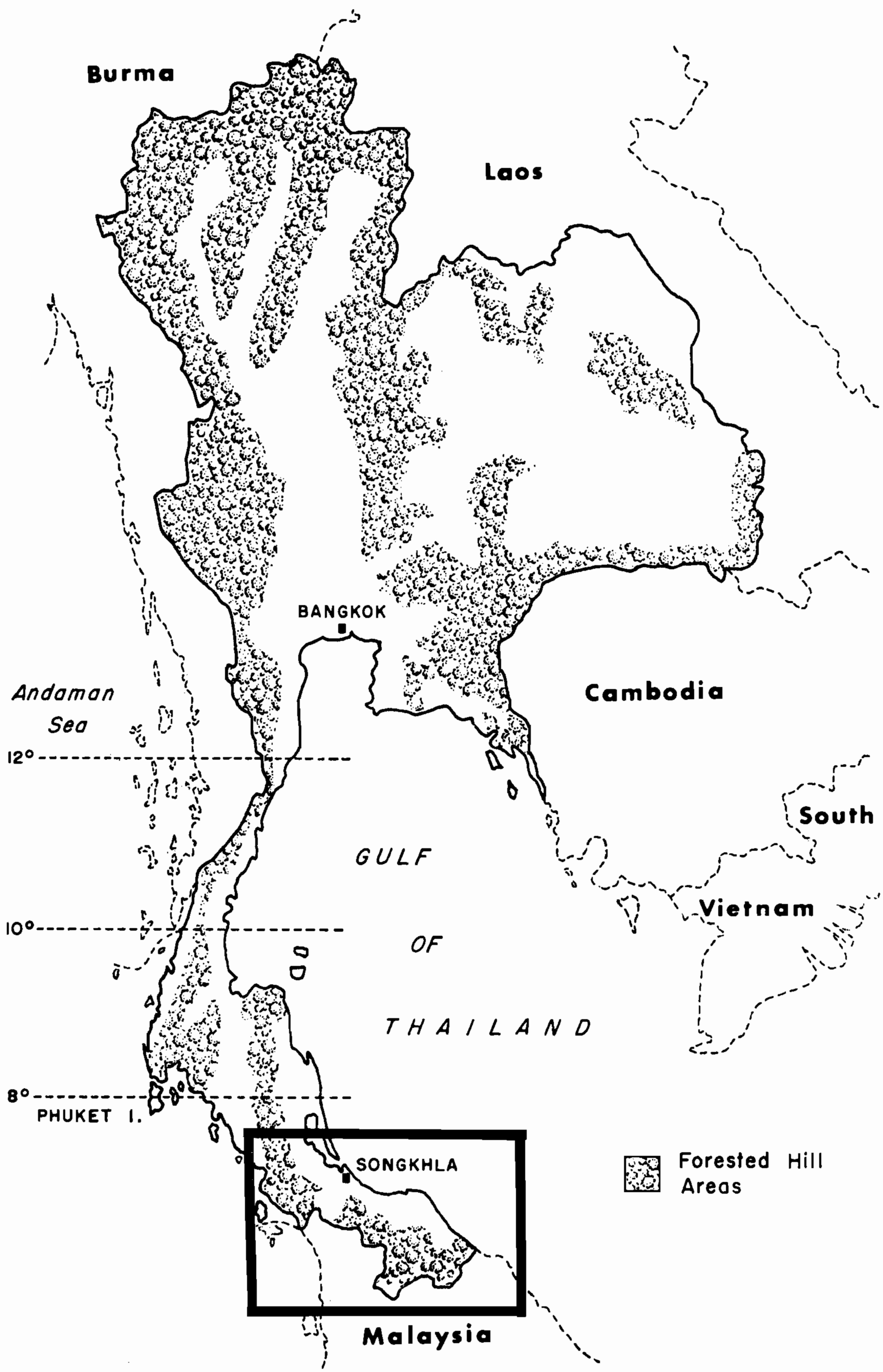

Figure 1 – Map of Thailand showing distribution of monsoon and evergreen forest areas. Rectangle indicates approximate area covered by Figure 2.

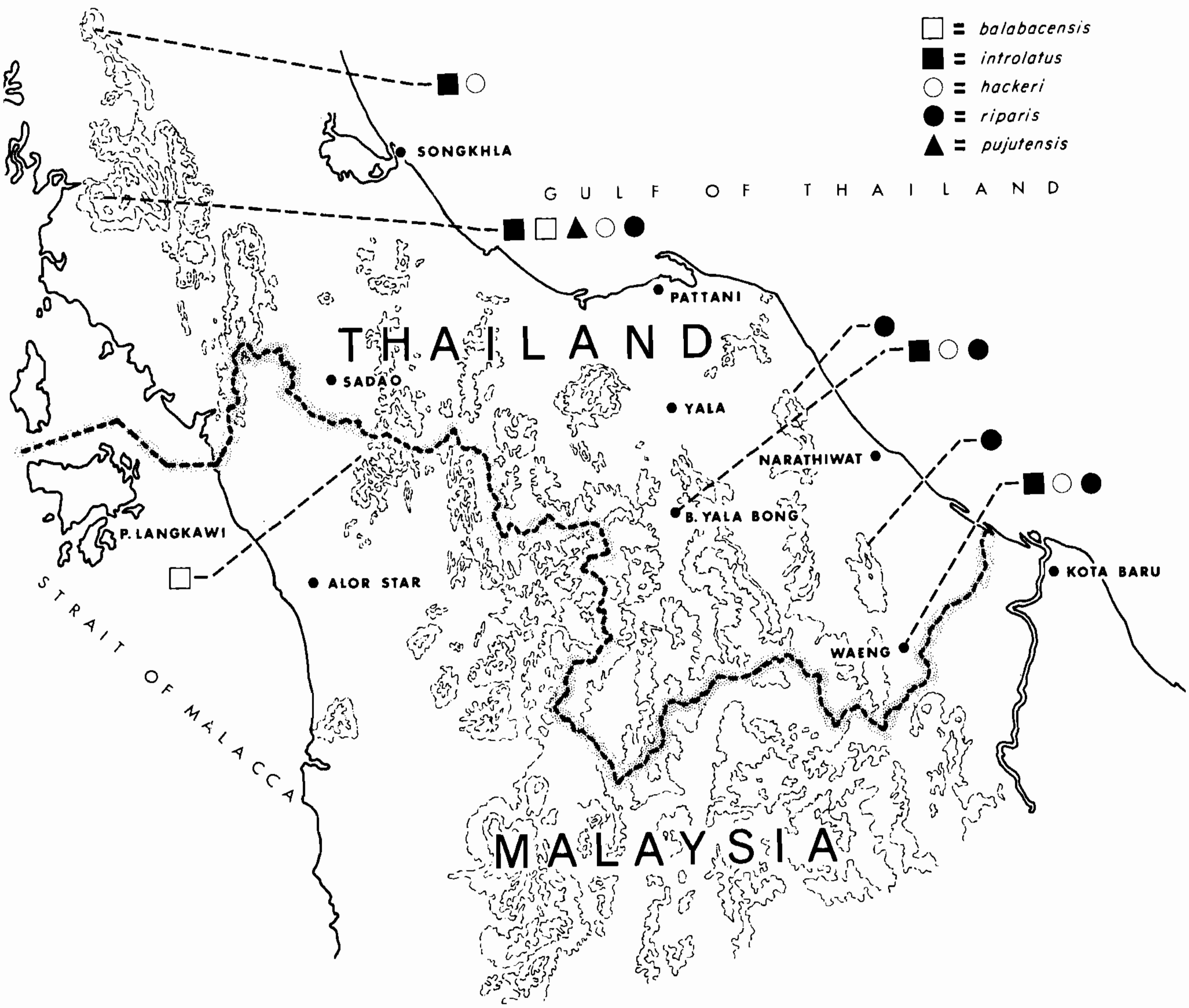

Figure 2 — Sites in Southern Tailand and Northern Malaya from which species of the *Anopheles leucosphyrus* group have been examined.

long collections are made. However, the general statement of Scanlon and Sandhinand appears to hold true —that one may expect to find *b. balabacensis* in any place in Thailand, north of the most southern Provinces, where forested hills or mountains are found. The area in figure 1 indicated as forested may be taken as a reasonably accurate guide to the distribution of the nominate form of *balabacensis* in Thailand.

The very large populations of *b. balabacensis* reported by Scanlon and Sandhinand (1965) for Cholburi Province in 1964 have not been encountered elsewhere in Thailand. Nor have such large numbers been found again in Cholburi. The site of the 1964 studies has been further deforested, and has received several heavy DDT treatments, and it is assumed that these factors combined to reduce the population. It does not appear, however, that very large populations of *A. balabacensis* are required to sustain malaria transmission in forested areas. In 1965 and 1966 small teams from SEATO, WRAIR and cooperating agencies conducted studies on forest *Anopheles* in the Pak Thong Chai District, in Nakorn Ratchisima Province, approximately 100 miles northeast of Bangkok. In the 1966 experiments approximately 6 percent of the *A. balabacensis* females examined were carrying sporozoites. During each year two members of the teams sustained *falciparum* malaria attacks (despite prophylaxis) while in the area or shortly after leaving it. One striking feature of each of these experiences was the small number of *balabacensis* captured (approximately 1-3 per man, per night) and the complete or almost complete absence of other *Anopheles* biting man at the time. It would appear that *balabacensis* is an extremely efficient malaria vector under these circumstances. Similar high sporozoite and malaria attack rates have been reported by SEATO and Thai Ministry of Health investigators in other areas of Thailand, but usually other known or suspected vectors, especially *A. minimus*, were also present in the areas studied.

Additional collections of adults and immature stages have been made by SEATO personnel in many areas of Thailand, from near sea level to as high as 4,800 feet on a mountain near the Cambodian border. Larvae have been found in many small water collections under shade. Elephant footprints appear to be a favored habitat, but any water-holding depression in the soil is a potential breeding site, provided it receives sufficient shade. With very few exceptions, however, the larval habitats seen have been shallow temporary pools that are frequently freshened by rain. The species has not been found in grassy pools or in larger semi-permanent pools with one exception discussed below. This form does not occur as frequently in rock pools as some of the other forms in the group. Scanlon and Sandhinand (1965) described an unusual larval site in sapphire pits in southeastern Thailand, and collections in 1965 and 1966 confirmed the continued high larval production in this niche.

The females are primarily exophilic, although they enter fairly open shelters to feed. Small numbers were collected in September 1966 at Pak Thong Chai in a Landrover in which a four man collecting team had taken shelter from extremely heavy rains. Females began entering the vehicle at approximately 11 p.m., apparently having flown through the rain from the surrounding jungle. This late night feeding pattern was observed in most collecting sites in Thailand, but SEATO personnel have occasionally found local populations where the females came to human bait much earlier in the evening. At times this early feeding pattern was very striking and similar patterns have been reported from several areas in Vietnam. No reason for this difference in feeding and activity pattern has been detected as yet.

Anopheles balabacensis is known to feed readily on monkeys in Thailand (Scanlon and Sandhinand, 1965) and in Cambodia (Eyles *et al.*, 1964). Eyles and his co-workers failed to infect any of seven rhesus monkeys inoculated with sporozoites of *balabacensis* origin in Cambodia. Cheong *et al.* (1965) later reported the isolation of *Plasmodium cynomolgi* and *P. inui* from *balabacensis* collected in Perlis, Malaya, near the Thailand border. Recently Gould *et al* (1966) infected splenectomized gibbons (*Hylobates lar)* in Thailand by inoculation of triturated *balabacensis* which had been permitted to feed on human *Plasmodium falciparum* patients some two weeks earlier. The possibility exists that *balabacensis* is also a natural vector of simian malaria in Thailand, but much additional work will be needed to establish the point. It is an excellent laboratory vector of several species of human and simian malaria (Coatney, 1966).

Several hundred adults and an equal number of immature specimens were examined during this review. No attempt will be made to list these, but a few localities in the far southern part of Thailand are indicated in figure 2. The locality in northern Malaya indicated for *balabacensis* is the approximate site where British Commonwealth troops encountered drug resistant *falciparum* malaria in 1963 (Montgomery and Eyles, 1963) and where Cheong *et al.* (1965) isolated simian parasites. There is no doubt that the specimens of *balabacensis* reported from that area were the nominate subspecies, as they were identified by workers who were very familiar with *balabacensis* and *introlatus*. This northwestern corner of Malaysia pobably marks the southernmost extension of the range of *balabacensis* on the Malayan peninsula.

Anopheles balabacensis introlatus Colless 1957

Colless (1957) assigned this name to the form which he had previously called *A. leucosphyrus* "Kepong Form." At that time *b. introlatus* was known only from the vicinity of the type locality in Malaya. Subsequently it has been reported from many areas of Malaya, apparently never in large numbers (Warren *et al.* 1963). It was first found in southern Thailand by collectors of the Royal Thai Ministry of Public Health in 1960 or 1961 according to unpublished reports. Localities from which SEATO collectors have reported *A. b. introlatus* are indicated in figure 2. Extensive collections elsewhere in Thailand failed to yield the species, except for a single male with associated larval and pupal skins, collected in Ranong Province, above 10° N. latitude which is tentatively identified as *b. introlatus*. Aside from this single specimen, all of the *b. introlatus* collected were from that portion of Thailand south of approximately 8° N. latitude. From the relatively few collections at hand it appears that the nominate subspecies may extend farther south on the west side of the Malayan Peninsula, while *b. introlatus* extends farther north on the eastern side. Several collections from the Waeng District of Narathiwat Province included adults which could not be placed in either subspecies with confidence. Most specimens for which associated larval and pupal skins were available were identified as *b. introlatus*, but a significant percentage were intermediate. These collections appeared to fit the criteria of an intermediate population as outlined by Mayr *et al.* (1953) and lend further weight to Colless's (1957) decision to regard *introlatus* as a subspecies of *balabacensis*. Additional collecting will be needed to define precisely the line of demarcation of the two subspecies. This is a matter of some practical interest, since *introlatus* has never been implicated as a vector of human malaria.

None of the specimens collected in Thailand by SEATO were from human or animal biting collections, but Wharton *et al* (1964) indicate that *b. introlatus* is attracted to human and monkey bait in Malaya. Two species of simian malaria parasites have been isolated from *b. introlatus* in Malaya, *P. cynomolgi* and *P. fieldi* (Wharton *et al*, 1964).

Immature stages were collected from the same general types of habitat as the nominate subspecies. Larvae were also found a number of times in the rocky stream pools more characteristic of *A. riparis*.

Anopheles hackeri Edwards 1921

This species was described from Malaya and also recorded from Borneo and doubtfully from Sumatra (Colless, 1955). The distribution in Thailand is given in figure 2. All of the SEATO collections have been of immature specimens, and the habits of the adults in Thailand are not known. In Malaya most studies on the species have been conducted in the coastal areas where the larvae and adults are strongly tied to a Nipah palm habitat (Reid and Weitz, 1961). However, Warren *et al.* (1964) note that the primary hill forest of central Malaya was originally thought to be the habitat of the species, the larvae being found in fallen bamboos, tree holes and ground pools. In the SEATO collections larvae were taken from a tree hole near ground level, rock holes and ground pools. Specimens from Thailand were compared with others from coastal areas of Malaya but no significant differences were detected.

A. hackeri has not been collected biting man in Thailand, and there is evidence from Malaya (Reid and Weitz, 1961) that it feeds preferentially on monkeys, rarely on man. It has been found naturally infected with sporozoites rather frequently in Malaya, and five species of simian parasites have been isolated from *hackeri* (Wharton *et al.* 1964).

Anopheles pujutensis Colless 1948

This is another of the species which appears to reach the northern limit of its distribution in the Thailand-Malayan border area. Colless (1955) reported it from Borneo, Malaya and Sumatra. Reid and Weitz (1961), Warren *et al* (1963) and Wharton *et al* (1964) gave additional data on the species in Malaya in connection with studies on simian malaria. The single confirmed Thai record is from Songkhla Province (Figure 2). Since this locality is so far north of the border and the known collection localities in Malaya it seems quite likely that it will be encountered farther south in Thailand in the future (subsequent examination of records indicates that *pujutensis* also was collected once in the larval stage in the Waeng District of Narathiwat Province). Reid and Weitz (1961) found that *pujutensis* was strongly attracted to monkeys in Selangor, Malaya, and showed serological evidence of biting man. Wharton *et al* (1964) reported similar results with precipitin tests. No adults were captured in Thailand. Reid and Weitz (1961) and Warren *et al* (1963) reported sporozoites in wild caught *pujutensis* in Malaya, but these were probably of simian origin. The precise role of *pujutensis* as a vector of simian malaria, however, is still in doubt. The serological evidence of feeding on man should probably be interpreted with caution, and the failure to capture the species in net traps with human bait may be more revealing. *A. pujutensis* appears to be fairly rare wherever encountered. The Thailand specimens were immatures, taken from stream side rock pools with *b. balabacensis* and *riparis macarthuri*. Similar sites were described by Warren *et al* (1964) in Malaya.

Anopheles riparis macarthuri Colless 1956

Colless (1955) described subspecies *macarthuri* for the form of *Anopheles riparis* found in Sarawak. Differences from the type form from the Philippines were mostly of a statistical nature, and Reid (1966) has expressed some doubt that the Malayan form deserves subspecific status. The reared adults from Southern Thailand were extremely variable, and on adult characters alone would be difficult to assign to either subspecies. However, the larvae and pupae were closer to *r. macarthuri* and the pattern of distribution of other species in the group lend weight to the maintenance of subspecific status for it. All of the Thailand specimens were taken in the immature stages and no observations were made on the adult habits. The adults appear to be quite secretive, as Wharton *et al.* (1964) found that while the larvae of *macarthuri* were the most common of the *leucosphyrus* group in the Malayan hill forest, only two adults were attracted to monkey bait. They stated that these were the first adults ever captured.

According to Warren *et al.* (1963) one of two adults of *A. r. macarthuri* taken from monkey bait yielded sporozoites which failed to infect monkeys on inoculation. It is likely however that this member of the *leucosphyrus* group is also a vector of simian malaria.

A. r. macarthuri larvae were most commonly taken from rock holes, stream-side pools and animal footprints along hill streams under forest cover. They appeared to be particularly abundant in areas near waterfalls.

Other Species of the *leucosphyrus* Group

During this study specimens of most of the other members of the *leucosphyrus* group in the USNM collection were examined in order to verify the identification of the forms found in Thailand. These included: *A. leucosphyrus* Dönitz (Malaya), *A. cristatus* King and Baisas, 1936 (Mindanao, Philippines), *A. riparis* King and Baisas, 1936 (Samar and Mindanao, Philippines), *A. balabacensis baisasi* Colless, 1957 (Luzon, Philippines) and *A. elegans* James, 1903 (Karwar, India). With the exception of the somewhat doubtful status of the form of *riparis* found in Thailand, none of these members of the *leucosphyrus* group occurred in the Thailand collections.

Discussion

Anopheles b. balabacensis is the only member of the *leucosphyrus* group found in Thailand north of the area close to the Malayan border. It is also the only member of the group found in the neighboring countries of mainland SE Asia north of Malaya. The reasons for this homogeneity, as opposed to the multiplicity of forms in South Thailand and Malaysia, may be found in the rainfall patterns in the respective areas and the resultant differences in vegetational cover and hydrography. Reid (1950) has commented in detail on several *Anopheles* species, including *A. minimus* Theobald, 1901, *A, annularis* Van der Wulp, 1884, and *A. ramsayi* Covell, 1927, which occur widely in mainland SE Asia but disappear south of the general area of the Thailand-Malaya border. As can be seen in figure 2, the mountains in this region run in a general north-south direction, and there does not appear to be any geographical barrier to the movement of species in the area. According to Reid (1950) the same discontinuity in distribution has been noted in butterflies, reptiles and amphibia. These more recent collections from Thailand again emphasize the strength of this barrier. This is a matter of some importance to Malaya, since *A. b. balabacensis* is the most important malaria vector in the species group, and its spread southward into Malaya could have serious consequences for the malaria eradication program just beginning there.

An examination of the climatological data for the area (Ohman, 1965) indicates that the 150 inch isohyet roughly approximates the southern limit of *A. b. balabacensis.* Reid (1950) also points out that the distribution of rainfall within the year may also be extremely important. In Malaya proper the rainfall is distributed fairly evenly throughout the year, with one or two periods of somewhat higher rainfall. In most of Thailand and the other countries of mainland SE Asia there is generally a distinct single monsoon period each year, with a marked contrast between wet and dry seasons.

Anopheles b. balabacensis seems to extend somewhat further into Malaya on the western side of the peninsula than on the eastern, (fig. 2). If confirmed by further collecting in the area this distribution may be due to the effect of the November and December rains from the China Sea which strike the eastern side of the peninsula, but contribute little rain to the western side. The latter region has a rainfall pattern similar to areas further north in Thailand, with rains from May to September and a prolonged dry period from October to May.

The border area is a particularly interesting one from the standpoint of zoogeography, and deserves much additional attention. Work in the area is however, somewhat hampered by the lack of developed roads and transportation, particularly during the wetter time of the year. Present plans of the government of Thailand for opening up forested areas to cultivation should make the task somewhat easier, and the settling of large numbers of farmers in previously virgin forest make it all the more important to define the distribution of the various members of the *leucosphyrus* group and their status as malaria vectors in the border region.

Summary

Anopheles balabacensis balabacensis is the most abundant and important member of the *Anopheles leucosphyrus* group in most of Thailand. It is found predominantly in the hill forests and is a potent vector of human malaria. In the far southern Provinces of Thailand it is replaced by *A. balabacensis introlatus*, and the latter subspecies extends southward into Malaya. In the vicinity of the border populations of *A. balabacensis* occur which cannot readily be assigned to either subspecies, but the nominate subspecies extends slightly into Malaya on the western side of the peninsula.

Three other members of the *leucosphyrus* group have now been found in the border area and somewhat northward into Thailand. These are: *A. hackeri*, *A. pujutensis* and *A. riparis macarthuri.* These seem to be absent above approximately 8° N. latitude in Thailand, probably because of the transition from a rain forest environment to a monsoon environment with a prolonged dry period which occurs in the rest of Thailand.

Anopheles balabacensis balabacensis is the only species listed which has been implicated in the transmission of human malaria. However, all of the species probably serve as vectors of simian malaria. Further investigation is needed on the distribution of the *leucosphyrus* group in the Thailand-Malaya border area, particularly from the aspect of determination of the precise climatic factors which influence this distribution.

Acknowledgments

The collections in Southern Thailand were made by various members of the Department of Medical Entomology, U.S. Army Medical Component-SEATO, often under very difficult conditions. Collections there were supervised by Dr. D. J. Gould and Master Sergeant E. L. Peyton, and the latter was responsible for many of the preliminary identifications. Mrs. Rampa Rattanarithikul of SEATO was responsible for some of the other identifications. Appreciation is also expressed to Dr. Botha de Meillon, SEAMP and Dr. Alan Stone, U.S. National Museum for their assistance and advice. The accompanying maps were prepared by Miss Thelma Ford, SEAMP.

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PRELIMINARY REPORT ON THE FEEDING PATTERN OF TWO SPECIES OF FISH IN A RICE FIELD HABITAT

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In the Sacramento and San Joaquin valleys of California, several species of fish thrive in a habitat created by the flooding of vast tracts of land for rice production. These fields which are flooded for at least four months during the warmer part of the year also provide conditions favorable for mosquito breeding. Although considerable work has been done on predation of mosquitoes by *Gambusia affinis* and other fish in rice fields and other habitats, most studies have been limited to observance of the interaction between the mosquitoes and the predatory fish with little regard to other organisms present in the environment. The more notable exceptions to this include studies (e.g., Hess and Tarzwell 1942; Harrington and Harrington 1960, 1961) undertaken in habitats quite unlike that of California rice fields. The present study was therefore designed to study the rice field environment and the food selection of four of the most common fish in this particular habitat. It is hoped that upon completion of this study, the results will help determine why greater control of mosquitoes often is achieved using predatory fish (*G. affinis*) in one rice field than in another.

In certain situations, determining the forage ratio has been useful in analyzing the predator-prey interactions of mosquitoes and fish. This ratio is based on a numerical expression of one population feeding on another and taking into account the availability of the latter, and was used effectively as a criterion in determining food preference of *G. affinis* in newly impounded waters of the Tennessee Valley (Hess and Tarzwell 1942). In many aquatic situations, however, a serious obstacle to this type of analysis has been the absence of objective data on food availability. This point has been emphasized by Hynes (1950) and Harrington and Harrington (1961). In an attempt to overcome this problem in our rice field mosquito ecology studies we have used aquatic light traps (Husbands, unpublished manuscript) to sample insect populations (Hokama and Washino 1966). Since field evaluations indicated that these traps were superior to other available tools (i.e., dipping, apron net, etc.) for sampling most aquatic insects other than Diptera larvae (Washino and Hokama, unpublished studies), we continued to use them in our rice field studies during 1966. In addition, four species of fish were sampled to study their food selection throughout the period that the rice fields were flooded. When the study is completed, the food selection of the four species of fish can be analyzed by both the forage ratio method (Hess and Tarzwell 1942) and by comparing the gut contents of the fish sampled (Harrington and Harrington 1961). Dissections of the alimentary tract have been completed for only two of the four species of fish, and the analysis of the aquatic insect population is incomplete. Therefore, this preliminary report will be limited to brief summaries of: (1) results of measuring some of the seasonal changes in a rice field habitat which may affect the interaction of fishes and mosquitoes; (2) results of examining the alimentary tract of the two most common species of fish; and (3) the seasonal distribution of some of the more common aquatic organisms observed as evidence by analyses of fish gut contents.

Procedure

The brief discussion summarizing environmental factors in a rice field habitat is based on unpublished studies conducted from 1963 through 1966 in the lower Sacramento Valley. Since this is primarily a progress report, details of sampling and analytic procedures will be included in a future and more finalized report.

Studies on the food selection of fish were undertaken during the summer of 1966 in a rice field in Sutter County. The 30-acre field was flooded May 2 and water was kept on the field until September 6. Naturally occurring carp (*Cyprinus carpio*) were observed in early May. Later in the month the field was stocked with approximately 4,500 *Gambusia affinis* by Sutter-Yuba Mosquito Abatement District personnel. By the first week of June it was evident that four species of fish were established in the field under study. In addition to *G. affinis* and *C. carpio*, these were the common bluegill, *Lepomis macrochirus*, and hitch, *Lavinia exilicauda*. The last three species were undoubtedly introduced from irrigation canals. Starting in June, fish were collected weekly with either a seine or with large screened cylinder traps (funneled at the two ends). However, uniform sampling of fish throughout the season was not possible owing to incidents such as the occasional draining of parts of the field by the farmers to control carp. As fish were collected they were killed instantly and brought to the laboratory where they were stored in ethyl alcohol until examined. The aquatic insects (including mosquitoes) were sampled weekly by means of two aquatic light traps and by dipping at fixed stations with an enameled pan (40 dips).

Results and Discussion

Seasonal changes in a rice field habitat. The changes in rice fields from the time of flooding and seeding until harvest are gradual but quite marked (Fig. 1). As the season progresses there is a tendency for a more constant thermal environment since the range in daily temperatures is gradually reduced. The same can be said for sunlight reaching the water surfaces. In addition, the total solar energy reaching the water surface decreases. The fluctuation in dissolved oxygen concentration increases as the season progresses although once irrigation is stopped, the oxygen concentration in the residual water remains rather low. Very little seasonal variation has been detected in ammonia nitrogen concentrations. Summer buildup and decline of submersed plants (e.g., water nymphs, *Najas* sp.) are gradual. Immersed vegetation builds up rapidly in early summer (e.g., arrowhead, *Sagittaria calycina*) but is reduced or eliminated by applying herbicides. Other plants (e.g., bulrush, *Scirpus mucronatus*, and cattail, *Typha latifolia*) continue developing into late summer. The most commonly observed algal succession in this type of habitat usually starts with the appearance of *Gloeotrichia* in dense mats early in the summer. *Spirogyra* or *Anabaena* tend to become dominant in midsummer. *Chara* is quite prevalent from mid to late summer. *Gloeotrichia* dominates the fields in late summer although not in the magnitude of early summer. Some aquatic crustaceans (e.g., tadpole shrimps, *Notostraca*, and clam shrimps, *Conchostraca*) appear shortly after flooding and then disappear while others (e.g., seed shrimps, *Podocopa;* copepods, *Eucopepoda;* and water fleas, *Cladocera*) can be observed throughout most of the summer. Most aquatic Coleoptera and Hemiptera reach a single seasonal peak in early summer, and a few in midsummer. Some Hemiptera have a second seasonal peak later in the summer, and at least one species of mayfly appears late in the summer. All of these factors illustrate the complexity of this ever-changing habitat, and emphasize the need for further studies on the interrelationship of mosquitoes with their environment.

Summary of the food taken by Gambusia affinis and Cyprinus carpio. Summary of the food items in the alimentary tracts of *G. affinis* is presented in Table 1. Feedings on crustaceans were generally high. Cladocera were the predominant food organisms. Immature forms of chironomids were second. It is assumed that most of the chironomid larvae consumed were the free-swimming forms which have evacuated their tubes (see discussion by Bay and Anderson 1966). Feeding on terrestrial insects (e.g., aphids, Diptera adults) was relatively high but not surprising in view of the surface feeding tendency of *G. affinis.* Feeding on larvae and pupae of *Culex tarsalis* was low, but numbers of *Anopheles freeborni* were moderately high.

The data for *C. carpio* are summarized in Table 2. As with *G. affinis,* crustaceans and immature chironomids were the most abundant food items. However, the differences between the behavior of carp and *G. affinis* are reflected in the considerably greater numbers of chironomids found in carp. In contrast to *G. affinis,* carp undoubtedly fed on benthic forms still in tubes as well as on free swimming larvae and pupae. Feeding on *C. tarsalis* was in comparable magnitude to that of *G. affinis,* but *A. freeborni* was not found in any of the carp examined. This may be indicative of differences in the behavior of the two fish (and the two mosquitoes), but might also be attributed to inadequate sampling since fewer carp were available for examination during later summer. With the exception of a few of the other organisms, differences in the food selection of the two fish were not as great as one might be inclined to expect. This probably reflects the influence on food selection of the relative availability of food types in the environment, and suggests the importance of careful quantitative as well as qualitative ecological evaluation when interpreting food preference data.

Interrelationship of the food selection by fish and the seasonal distribution of the aquatic insects. Inasmuch as a complete seasonal analysis of aquatic insects and crustaceans has not been completed, a final analysis is not yet possible. A few general comments can be made, however, on apparent basic patterns of predation evidenced by examination of gut contents of the two species of fish (Tables 1 and 2) and on seasonal distribution and density data for some of the more common insects sampled (Table 3).

The first pattern is exemplified by the predatory response of carp and *G. affinis* to chironomids. Immature chironomids reached peak abundance during the

Table 1. Summary of food items in the alimentary tract of 197 *Gambusia affinis,* 1966.

Food Item	Food Item per fish x 10
Nematode	.05
Crustacea-Cladocera	62.57
Podocopa	8.92
Eucopepoda	7.03
Arachnida-Acarina	0.51
Insecta-Ephemeroptera (Baetidae)	0.21
Odonata (Zygoptera)	0.21
Hemiptera-Homoptera	
Gerridae	1.49
Corixidae	0.82
Aphidae	7.69
Cicadellidae	0.56
Misc.	0.31
Coleoptera	
Tropisternus lateralis	0.10
Laccophilus sp.	0.10
Misc.	0.21
Hymenoptera (Formicidae)	0.15
Diptera	
Chironomidae (larva-pupa)	42.26
Chironomidae (adult)	8.36
Stratiomyiidae (larva)	0.26
Tipulidae (larva-pupa)	0.56
Tipulidae (adult)	1.85
Culex tarsalis (larva-pupa)	0.40
Anopheles freeborni (larva-pupa)	6.40
Muscoid flies (adult)	0.05
Misc. (larva-pupa)	0.62
Misc. (adult)	8.26

last week of May and the first three weeks of June (Table 3). Maximum predation by carp on this food source occurred during the first two weeks of June and relatively high chironomid predation by *G. affinis* during the first three weeks of this month. This appears to identify a clear picture of peak abundance of the prey population (chironomids) followed by maximum predation by the two fish predators.

In the second pattern observed, water boatman nymphs and adults (*Corisella sp.*) occurred in peak numbers during the first two weeks of June (Table 3).

Table 2. Summary of food items in the alimentary tract of 104 *Cyprinus carpio*, 1966

Food Item	Food Item per fish x 10
Nematode	0.00
Crustacea-Cladocera	51.90
Podocopa	3.17
Eucopepoda	12.60
Arachnida-Acarina	0.00
Insecta-Ephemeroptera (Baetidae)	0.00
Odonata (Zygoptera)	0.00
Hemiptera-Homoptera	0.00
Gerridae	0.00
Corixidae	5.67
Aphidae	0.19
Cicadellidae	0.00
Misc.	0.00
Coleoptera	
Tropisternus lateralis	0.29
Laccophilus sp.	0.10
Hydrophilus triangularis	0.10
Misc.	0.00
Hymenoptera (Formicidae)	0.10
Diptera	
Chironomidae (larva-pupa)	475.48
Chironomidae (adult)	4.04
Stratiomyiidae (larva)	0.10
Tipulidae (larva-pupa)	0.38
Tipulidae (adult)	0.19
Culex tarsalis (larva-pupa)	0.48
Anopheles freeborni (larva-pupa)	0.00
Muscoid flies (adult)	0.00
Misc. (larva-pupa)	0.29
Misc. (adult)	8.17

Table 3. Weekly aquatic light trap and dipping collections of four aquatic insects from a rice field in Sutter County, California. 1966.

		Aquatic light trap collection		Dipping collection	
Collection Period		Chironomidae larvae and pupae	Corisella sp. nymphs adults	*Culex tarsalis* larvae and pupae	*Anopheles freeborni* larvae and pupae
May	8	0	1	1	0
	15	0	1	0	1
	22	0	52	0	0
	29	81	32	1	0
June	5	143	1318	25	0
	12	51	591	3	0
	19	30	97	18	0
	26	2	64	39	1
July	3	4	94	17	0
	10	2	0	17	14
	17	9	28	6	16
	24	53	7	2	13
	31	8	2	0	18
Aug.	7	9	1	0	39
	14	38	2	1	9
	21	7	1	1	6
	28	1	0	1	8

Peak predation by carp occurred in the second week. This is similar to the above pattern, but in this instance the second predator, *G. affinis*, did not start feeding on these insects until the last week of June after their numbers had decreased considerably.

The third pattern is illustrated by the predation on mosquitoes. *C. tarsalis* reached its peak in June, the only period during which specimens were found in carp. There was no evidence of feeding on this species by *G. affinis* until July, and peak feeding did not occur until August when the *C. tarsalis* population was low. As soon as anopheline larvae were easily detectable (week of July 10) they were also found in *G. affinis*. Peak predation on anophelines was observed two weeks after their peak population had been observed.

While the number of fish examined was small, it was tentatively concluded that the abundance and wide variety of organisms present in early summer (June) probably provides food conditions approaching optimum for the fish. In late summer, food availability appears to decrease considerably so that smaller numbers and fewer types of organisms are available as fish food. This may intensify predation on mosquitoes, especially on *A. freeborni* which annually reaches its seasonal peak in late summer.

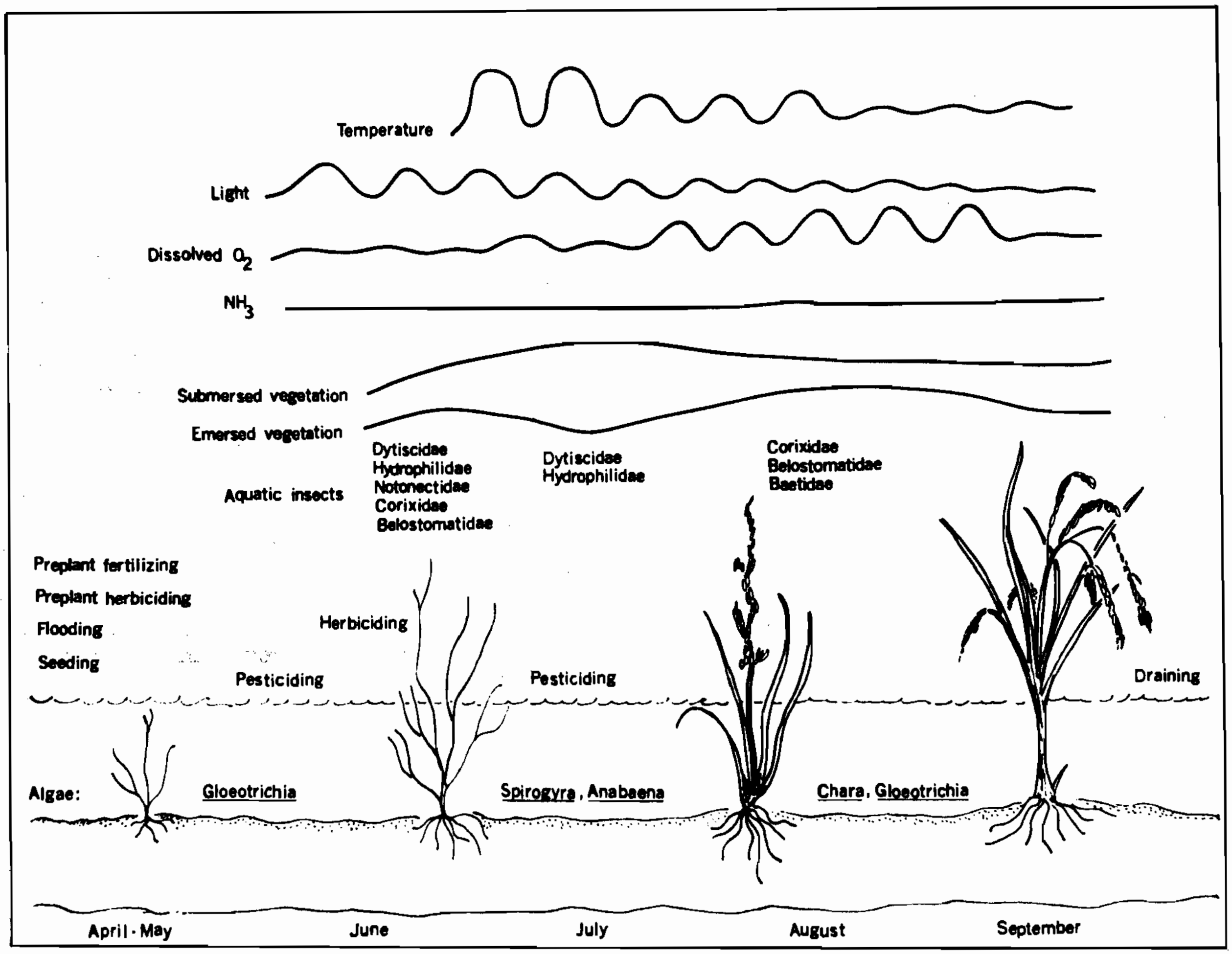

Figure 1 – Schematic representation of some factors in a rice field habitat.

Summary

Seasonal changes in the biological, chemical, and physical factors in a rice field habitat combine to accentuate the complexity of this environment.

The results of examining the alimentary tracts of 197 *Gambusia affinis* and 104 *Cyprinus carpio* are summarized. In both species, the amount of feeding on crustaceans and the immature forms of chironomid midges was high. Feeding activity on larvae and pupae of *Culex tarsalis* was similar in the two fish. No feeding by carp on *Anopheles freeborni* was detected.

Peak abundance of chironomids occurred in early summer and was followed immediately by maximum predation by the two fish. Peak abundance of water boatman (*Corisella sp.*) was followed immediately by high predation by carp but not by *G. affinis*. Carp fed on *C. tarsalis* only during the latter's seasonal peak in June. *G. affinis* fed on *C. tarsalis* in July and August, particularly in the latter month when the mosquito population was extremely low. It also fed on *A. freeborni* after July with highest predation occurring two weeks after the seasonal anopheline population peak.

It was tentatively concluded that the decrease in the abundance of most other aquatic organisms in late summer results in a more intensive predation by fish on late summer organisms such as *A. freeborni.*

Acknowledgments

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ECOLOGY AND CONTROL OF *LEPTOCONOPS KERTESZI* BITING GNATS IN SOUTHERN CALIFORNIA

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ABSTRACT

The diurnal, anthropophilic ceratopogonid *Leptoconops kerteszi* Kieffer is a serious pest in southern California desert areas. The gnats breed in damp sand along watercourses, around desert springs, and in an extensive marsh along the north shore of the Salton Sea. Gnats from this latter site attack tourists and vacationers at the nearby Salton Sea State Park. Laboratory and field studies on the gnats' life cycle and ecology preceded control investigations. Length of life cycle, aspects of reproductive physiology, and methods of feeding and rearing were determined in the laboratory. Repeated attempts to establish a self-maintaining laboratory colony were unsuccessful: gnats could not be induced to mate in confinement. In the field, the seasonal fluctuation of gnat populations, patterns of daily flight and attack activity, the nocturnal resting niche and preferred natural hosts of adults were determined.

Cultural control effectiveness was demonstrated by reducing the moisture of breeding grounds to less than 5% by weight. Where feasible, drainage provides effective, permanent control. Small plot larvicide tests were conducted in breeding grounds at the State Park with emulsion sprays and granular applications of 8 organophosphates, 2 chlorinated hydrocarbons, and a carbamate. Criterion for control was the reduction in larval and pupal populations in posttreatment soil analyses compared to populations in untreated plots. Diazinon and dieldrin applied as 1 and 2 pound per acre water base sprays were most effective, and conferred good control for 2 months during the summer of 1965. Twenty acres of gnat breeding ground received an aircraft-applied treatment of diazinon (2 pounds per acre) on January 15, 1966, and gnats were virtually eliminated for 4 months. The cool soil surface temperatures, and the timing of the application immediately prior to the spring emergence period contributed to the success of the large scale test. Gnats from surrounding untreated desert areas reinvaded the State Park breeding ground in the summer and fall of 1966.

SUBMITTED PAPERS SESSION

CONCURRENT

TUESDAY, FEBRUARY 7, 1:30 P.M.

MAURICE W. PROVOST, *Presiding*

CURRENT STATUS OF THIRD UNITED STATES ARMY *Aedes aegypti* ERADICATION PROGRAM

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The Third United States Army 1966 *Aedes aegypti* Eradication Program was conducted with the same objectives as those established in the 1965 program. The surveys are conducted on a building-by-building, block-by-block basis on all Class I, II and inactive Army installations in the Third Army Area. The program is divided into three phases: (a) Preliminary surveys to determine the location and extent of mosquito breeding; (2) Contol measures to eliminate infestations, and (3) Post control surveys to determine the effectiveness of the control program. The basic objective of the program is to find all real and potential *Aedes aegypti* breeding sites and to completely eradicate this mosquito from all Army installations in the area. A secondary objective, one not presently accomplished by the U.S. Public Health Service in its program, was started in 1965 and continued through the 1966 program. This objective is that of locating all mosquito breeding sites on each installation and keeping records of all mosquito species collected. As will be discussed later, this secondary objective has provided extremely valuable information regarding pest mosquitoes and disease vectors other than *Aedes aegypti.*

The 1966 Third United States Army *Aedes aegypti* Eradication Program began on May 4 with a two day survey procedures training course for the survey team. The survey team consisted of one officer (3315) and fourteen enlisted Preventive Medicine technicians from the 714th Preventive Medicine Unit (Svc) (Fld), from Fort Bragg, North Carolina. Since insect control does not fall under medical channels, this team was specifically trained in collecting techniques with only slight training in source reduction and control. Immediately after completion of the training course, the team began surveying Third United States Army installation. From May 9 to October 4, this team surveyed fourteen installations. To augment the program, three or four man survey teams were organized from personnel of the Entomology Branch, Third United States Army Medical Laboratory. At the expense of the normal laboratory missions these teams managed to survey six other Third United States Army installations. Even with the added help of teams from the laboratory, only twenty installations were surveyed, leaving thirteen other installations unsurveyed. Only four installations were surveyed during the 1965 program.

The following seven installations, with dates of survey, were found positive for *Aedes aegypti:*

1. Fort Gordon, Augusta, Georgia, May 27-June 11, first survey.
2. Fort Rucker, Ozark, Alabama, June 20-24, second survey.
3. Fort Benning, Columbus, Georgia, June 27-July 14, second survey.
4. Alabama Army Ammunition Plant, Childersburg, Alabama, July 11-14, first survey.
5. Fort McClellan, Anniston, Alabama, August 1-3, second survey.
6. Anniston Army Depot, Anniston, Alabama, August 4-5, second survey.
7. Fort McPherson, Atlanta, Georgia, August 22-24, first survey.

It should be noted that Forts Rucker, Benning, and McClellan and Anniston Army Depot, the four installations surveyed during the 1965 pogram, were all positive for the second year in a row.

Only one *Aedes aegypti* breeding site was found at Fort Gordon, Georgia. This correlates with U.S. Public Health Surveys in adjacent Augusta, which was found moderately infested. As will be discussed later, this survey was conducted extremely early in the year, thus, it is suspected that the *aegypti* population on Fort Gordon is much larger than indicated by this survey.

Fourteen *Aedes aegypti* breeding sites were found at Fort Rucker, Alabama, this year, compared with thirty-five sites found last year. The large drop in number of positive sites found this year should not be interpreted as a drop in the numbers of *aegypti* on Fort Rucker. The main reason for the difference in the number of positive sites is probably due to the times of survey. The 1965 survey was conducted in August during the optimum time of *aegypti* breeding, while the 1966 survey was conducted in June, early in the breeding season of this mosquito, when it is still building toward maximum numbers reached in the late summer and very early fall.

In 1966 twenty-one *Aedes aegypti* breeding sites were found at Fort Benning, Georgia, while nineteen such sites were found there during the 1965 survey. The 1966 survey was conducted from June 27 to July 14, still early in the season for maximum numbers of *aegypti.* The 1965 survey was conducted from September 9-24, the period of maximum *aegypti* numbers. It should be noted that the 1966 survey was much more extensive than the 1965 survey, with over 100 more mosquito breeding sites found this past year than the earlier year. Another interesting find during the 1966 survey was the change in the distribution of *aegypti* since the 1965 survey. Major areas found positive for this species in 1965 were found negative in

1966, and major areas found negative in 1965 were found positive in 1966. With the above information it is concluded that the *Aedes aegypti* population at Fort Benning has not significantly changed during the year except for its distribution.

Alabama Army Ammunition Plant, Childersburg, Alabama, was surveyed for the first time in 1966 and nine positive *aegypti* breeding sites were found. This survey provided some extremely interesting information for further surveys. Maybe the most important disclosure was *aegypti* found in large numbers approximately 3500 feet from the proximity of the nearest humans. Since *aegypti* is usually thought of as being basically a human feeder, breeding in close proximity to man, the U.S. Public Health Service established its survey program on this basis eliminating remote, rural areas as probable breeding sites. Further discussion of the implications of this find will be thoroughly presented later in this paper.

Two positive *Aedes aegypti* breeding sites were found at Fort McClellan, Anniston, Alabama, during the 1966 survey, while three positive *aegypti* sites were found in 1965. The 1966 survey was conducted from August 1-3, and the 1965 survey from September 27 to October 6. With such a low rate of infestation, *aegypti* can probably be extirpated from this post within the next couple of years barring an influx of specimens from outside sources.

The 1966 survey revealed two breeding sites of *aegypti* at Anniston Army Depot, Anniston, Alabama. The survey found *aegypti* at only one site on this installation. This installation, like Fort McClellan, is a prime candidate for complete extirpation of *aegypti* in the next couple of years. Again, this can only come true provided an influx of specimens from outside areas does not occur.

In 1966, the first *Aedes aegypti* survey of Fort McPherson, Atlanta, Georgia found one positive breeding site of *aegypti;* however, two weeks after the survey was completed another positive *aegypti* site was located on this post some distance from the initial site. With such a small area as Fort McPherson and with a low density of *aegypti* it would seem probable that this species could easily be extirpated from the post. However, a program of constant control would be needed to eliminate reinfestation from surrounding Atlanta. This city has been found moderately infested and at least one large *aegypti* breeding area is known to be located within 150 yards of Fort McPherson.

The remaining thirteen installations with dates of survey, were surveyed for the first time and all were negative.

1. Fort Jackson, Columbia, South Carolina, May 9-18.
2. Charleston Army Depot, North Charleston, South Carolina, May 15-20.
3. Fort Stewart, Hinesville, Georgia, May 19-25.
4. Memphis Defense Depot, Memphis, Tennessee, June 12-16.
5. Atlanta Army Depot, Forest Park, Georgia, June 10-17.
6. Mountain Ranger Station, Dahlonega, Georgia, July 27-28.
7. Milan Army Ammunition Plant, Milan, Tennessee, August 1-5.
8. Fort Campbell, Kentucky, August 8-25.
9. Volunteer Army Ammunition Plant, Chattanooga, Tennessee, August 29-31.
10. Holston Army Ammunition Plant, Holston, Tennessee, September 6-8.
11. Charlotte Army Missile Plant, Charlotte, North Carolina, September 13.
12. Military Ocean Terminal, Sunny Point, North Carolina, September 12-16.
13. Fort Bragg, Fayetteville, North Carolina, September 20-October 4.

The population of *aegypti* found in 1966 at Alabama Army Ammunition Plant, Childersburg, Alabama is very significant. The nine positive *aegypti* sites at this installation yielded 977 specimens of this species, indicating a very heavy population density. Even more significant is the fact that all nine sites were at least 300 yards from the proximity of the nearest humans, with one-third of the sites being approximately 3500 feet away from humans. The only time a human came near these latter sites was once a day when a guard drove by about 50 to 100 yards away. The current U.S. Public Health Service *Aedes aegypti* Eradication Program was established on the premise that *aegypti* is basically an anthrophilus species. For this reason and the premise that *aegypti* normally has a short flight range of about 100 meters, the eradication program was placed on an urban scale, with no plans for surveillance or eradication of rural populations, if they existed. Evidence began to accumulate in 1965 that rural populations did exist, and the *aegypti* population at Alabama Army Ammunition Plant definitely established this fact.

Immediately after finding the *aegypti* population at this Ammunition Plant, the *Aedes aegypti* Eradication Branch, U.S. Public Health Service, was notified and they promptly sent a team to verify the findings. During this visit, several engorged female *aegypti* were captured and precipitin tests were conducted to pinpoint the source of their blood meals. These tests showed that the females had fed on cattle, of which there are about 300 grazing around the area. During the initial Army survey, it was noted there was a dense rodent and deer population in addition to the herd of cattle in the area of the *aegypti* breeding sites. Since these *aegypti* are known to be feeding on animals other than man, the Entomology Branch, Third United States Army Medical Laboratory has initiated research on the feeding habits of *aegypti* with plans for large scale research on the feeding habits of the Alabama population in 1967. Utilizing a small population of *aegypti* from the Atlanta, Georgia area, the Third United States Army Medical Laboratory has gotten excellent initial results from feeding *aegypti* on the Eastern Garter Snake, *Thamnophis sirtalis sirtalis.*

With the increased knowledge of *aegypti* ethology obtained from the survey at Alabama Army Ammunition Plant, it is the opinion of the personnel of the Third United States Army Medical Laboratory that the *aegypti* eradication program in the United States will be a long term program.

As noted earlier, a significant change was found in the distribution of the Fort Benning, Georgia, *aegypti* population, between 1965 and 1966. Large areas that were positive for this mosquito in 1965, were negative in 1966, and the reverse was also found. Such shifts in distribution may be partially attributed to control measures; however, the major reason is probably due to the constantly shifting human population on this post. Personnel on this military installation are constantly moving, both within and on and off the installation. Such movements most certainly account for frequent transportation of *aegypti* eggs and the relocation of adults. Columbus, Georgia, which is adjacent to Fort Benning is heavily positive for *aegypti*, thus there must be frequent movement of this species back and forth between the two communities. Any attempt to eradicate *aegypti* from Fort Benning would be futile without a corresponding program in Columbus. At pesent both communities have active eradication programs and these will probably continue until joint eradication can be declared. Similar situations exist between other Third United States Army posts and adjacent cities and it is expected that similar changes in the distribution patterns of *aegypti* will occur as the program progresses.

Information gathered during the two years of survey, indicates the peak period of *aegypti* activity and population density occurs between August 1 and September 20. This period is the ideal time for installation surveys; however, it is impossible to survey 33 installations in this short period. Consequently, this laboratory has a rotation program scheduled that will provide a survey of each installation during this period at least once every three years. Although the use of this rotation program will probably yield somewhat conflicting information from year to year, each installation will be surveyed at least once when *aegypti* is most abundant.

Numerous other mosquitoes have been collected with *Aedes aegypti*. The species most commonly collected with *aegypti* in the Third United States Army area are *Aedes triseriatus*, *Culex quinquefasciatus* and *Culex restuans*, in that respective order of abundance. Mosquitoes less frequently collected with *aegypti* are *Culex territans*, *Orthopodomyia signifera* and *Toxorhynchites rutilus*. Several other species have been collected with *aegypti*, but they do not require attention since they are not usually found breeding in containers.

Plans for 1967 include improved methodology, such as utilization of the oviposition jars. In addition, two fourteen man teams will be sent to this field in May to initiate surveillance programs on all active and inactive installations within the area.

THE *AEDES VEXANS* PROBLEM

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Last year at our annual meeting in Atlanta, Georgia, my good friend, Tommy Mulhern, asked me if I had any ideas as to what should be discussed at the next meeting of this Association. My off-the-cuff answer at that time was *Aedes vexans*. As a result of this conversation, and several letters between California and Nebraska, I am here today to discuss briefly and present some of my views on this mosquito.

Of all the mosquitoes which we, as mosquito control workers, must deal with, *Aedes vexans* is found everywhere in North America. It is probably one of the most widely distributed nondomestic species of mosquitoes. In some areas, it is only of local importance, while in other areas, it is the dominant mosquito.

This mosquito has the unfortunate, as well as unpleasant, habit of being an extremely vicious biter, and, when it occurs in large numbers, it can make the entire population very uncomfortable and can even drive the hardiest of souls indoors. Although it is usually considered to be a twilight biter, when populations are high, it becomes a serious daytime biter as well.

Studies which we have conducted in Nebraska have shown that it can be the principal mosquito that bites babies left out-of-doors during the daylight hours for sleeping. We have had several babies hospitalized as a result of the bite of *Aedes vexans*.

Going back and looking into the historical aspects of this species, we find that early writers such as John B. Smith, the pioneer of New Jersey mosquito work, in his early reports, described this species as a severe biting and annoying form. From that time onward, every writer who has mentioned this species has also mentioned its biting abilities. To me, there is no doubt that, at the present time, this is probably the number one pest mosquito in the United States. I believe that we can honestly say that more people are affected by this one species than by any other species of mosquito. Yet, it is extremely interesting to note that we have done very little to gain a better understanding of *Aedes vexans*.

In gathering data for this short paper, I have reviewed most of the literature published during the past fifty years on North American mosquitoes, and it is interesting to find that the same statements were appearing in the early 1940's that are appearing in our literature today. I will grant you that we have made some interesting advances in studying the physiology and genetics of this species, but we have not gained much information which will allow us to better control this species. There is still, for example, a tremendous amount of controversy when one reviews the work of some of our outstanding students of mosquitoes as to wether there is one set of eggs laid per breeding season, or whether the eggs are laid at several different times during the breeding season. Some workers maintain that the eggs are laid by the early mosquitoes and then hatch at different intervals throughout the summer whenever the necessary water is present. Other students maintain that every time these areas flood, the eggs hatch, adults emerge, mate, and repeat the process of egg laying. No one appears to be completely sure of just how this phenomenon goes on. We have always assumed that this is strictly a flood water species, yet when one reviews the literature, there are questions left in one's mind. I have personally collected larvae of this species in sewage lagoons and in run-off pits in the oil fields of southeastern Nebraska. These are permanent bodies of water, yet we have found larvae known as flood-water mosquitoes.

A question that constantly comes up in my mind when dealing with *Aedes vexans*, is just how important is this species from the medical point of view. Very few of us have made door-to-door canvasses to determine how much discomfort is being caused to the population by mosquitoes. True, we do this when we have a disease outbreak problem, but how about when we have simply a large population of mosquitoes which is causing a great deal of discomfort to the population?

I have discussed this subject with doctors on numerous occasions, and I am always interested in hearing the number of cases of mosquito bites which they have had to treat. Most of these cases are in children under the age of five, and I am sorry to say, it is not just one or two per year, but often 10 or 15, and one hears occasionally of cases where the doctor has been forced to hospitalize a child because of excess mosquito bites.

As a result of my reviewing the literature on *Aedes vexans*, I am certain that I could write a very interesting paper entitled, "Facts on *Aedes vexans*," because in my reading I found statements to the effect that they could fly eight miles out to sea, they could fly as high as a mile, and many other facts of this nature. Unfortunately, I could not locate a good life history of this mosquito. Possibly this mosquito is too difficult to work with for the average entomologist interested in mosquitoes. Maybe we have been licked by the commonest of mosquitoes found in the United States. There may be more elements of truth in this last statement than many of you are willing to concede. I can well recall that in the very early 1950's, the Water Resources Section of the Communicable Diseases Center of the U.S. Public Health Service maintained a field laboratory in Western Nebraska. The supposed purpose of this group was to study the relationship of irrigation to mosquitoes. After two years of work, they published the statement that their studies indicated that *Aedes vexans* was the most common mosquito in the irrigated areas of Western Nebraska. In spite of the fact that they had taken very large numbers of *Aedes vexans* in their light traps, they did not know where they were coming from. Although *Aedes vexans* was the most abundant mosquito found on this project, no time was spent studying this mosquito. Other species which were found in far less numbers were concentrated upon.

It is always interesting to me to recall how fast we can forget certain statements that we wish had never been said, and whenever I think of the Mitchell Field Station of the United States Public Health Service, which was established early in 1951, I recall a statement made by Acting Surgeon-General W. F. Dearing on Oct. 12, 1950: "It is our conviction that pest mosquitoes should receive more attention from health authorities than they have in the past. Public health has become something more than the absence of disease. Physical efficiency and comfort, on which mental equanimity depends to a substantial degree, may be seriously disturbed by the continued annoyance of pestiferous mosquitoes which may or may not have disease-transmitting potentialities. This principle has already been recognized by the Departments of the Army and of the Air Force in the development of pest mosquito control methods to be used for the protection of troops in the Arctic."

I will grant that this statement is over 16 years old and that many of the "brilliant young research workers" feel it greatly beneath their dignity even to think about, let alone carry out a directive made back in the dark, dead ages of 1950. However, to those of us who are engaged in the daily business of controlling mosquitoes, I sincerely believe that this statement has a tremendous amount of value. We are today, for the most part, controlling pest mosquitoes in the United States. I will not belittle the fact that nearly every year, we have an outbreak of some form of encephalitis which reaches an epidemic of local importance. However, the vast majority of those of us who are here at this meeting are engaged in trying to control pest mosquitoes, and *Aedes vexans* is such a mosquito.

I sincerely believe that it is time the American Mosquito Control Association goes on record as trying to encourage some good studies and research on this common mosquito. There are many factors which we as control people need to know, which have not been found. As I pointed out earlier in this paper, we still do not have a good life history of this mosquito. This could be a starting point and I think as a result of this work, we could learn something which would help us do a better job in controlling this particular species. In closing, I would again like to throw out to you who are attending this meeting that here is a challenge that we, or somebody, must take up. It is my personal belief that in a day and age when we can send a rocket around the earth for several days at a time, or a rocket around the moon, we can find out how to lick the problems which are caused by this simple little mosquito—*Aedes vexans*.

EFFECTS OF LOW-LEVEL ULTRA-VIOLET IRRADIATION ON REPRODUCTION OF *AEDES AEGYPTI* (L.) (Preliminary Report)

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Abstract

Adult males and females of *Aedes aegypti* (L.) were irradiated with a 4-watt fluorescent tube having a large proportion of its output at 2537A. Irradiation was for ½ to 8 minutes at a distance of 5/16". Mortality in the males was 2-5% for up to 4 mins. exposure, up to 45% for 8 mins. Four minutes and 8 minutes reduced mean longevity by 28% and 50%, respectively. Progeny from females paired individually with irradiated males were reduced by 46%, 89%, 96% and 99.8% by ½, 1, 2 and 4 mins., respectively. When 100 treated males were caged en masse with the same number of virgin females, 1 min. irradiation reduced mating by 6% and progeny by 25% while 2 mins. irradiation reduced mating by 31% and progeny by 57%. When females were irradiated, mortality was negligible over the whole range. Bloodfeeding was reduced by 55% by 2 mins. exposure and 97% by 4 mins. Overall reduction of progeny was 19, 70, 88 and 99% for ½, 1, 2 and 4 mins. exposure, respectively. Full results will be published in "Mosquito News" on completion of the experiments.

PROBLEMS OF INTERACTION AND DENSITY IN MOSQUITOES IN RELATION TO *AEDES AEGYPTI* ERADICATION

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The purpose of this paper is to raise questions and draw attention to some neglected aspects of the biology of *Aedes aegypti* and indeed other pest mosquitoes in general. It is dangerous to predict the outcome of the eradication campaign of *A. aegypti,* but the odds that it will succeed are good. Nevertheless, with our wisdom tempered by the history of past eradication programs, there are no grounds for unqualified optimism. We must admit that a gamble is involved with taxpayers' money. We hope that the consequences of the eradication campaign of *A. aegypti* will resemble more that of the screwworm than that of the gypsy moth; more that of the Mediterranean fruit fly than that of the fire ant (Brown, 1961.)

We should not argue that it is too late for basic studies on *A. aegypti* to have effect before the campaign ends, since this ignores the possibility that the goal might not be met by the target date. Whatever the result of the operation in the United States, further knowledge of *A. aegypti* will be needed before eradication can be attempted in its greater stronghold in Southeast Asia, where its contribution to human discomfort is undeniably greater. Whereas it may be true that we know more about *A. aegypti* than any other mosquito, it is not how much we know, but what we know, that matters, and more particularly what we know in relation to new and developing concepts in biology.

First it must be emphasized that we are dealing with a special type of world-round pest. *A. aegypti* belongs to that group of living organisms, animals as well as plants, which can be called weeds. It is an actively colonizing species which thrives in a man-altered environment. It is not a pest in the sense of the grain beetles, the Hessian fly or the pink bollworm which exploit clearly defined niches greatly expanded by man's intensive culture. Huts on the Red Sea coast, an auto junk yard in Alabama and slum houses in Singapore are greatly contrasting conditions and climates, yet all suit *A. aegypti.* Among other weedy insects *Drosophila simulans* invite comparison with *A. aegypti.* It is almost cosmopolitan, being less limited by cold than is *A. aegypti,* and is nearly everywhere closely associated with the messed-up environment of man. A most interesting similarity is that *D. simulans* has been found far away from man in Brazil (Dobzhansky, 1965) like the African forest form of *A. aegypti* (Mattingly, 1957). Geneticists currently favor the opinion that weedy species of both plants and animals may differ somewhat in the way they interact with, and adapt to, the environment. Two alternative genetic mechanisms seem to have characterized the invasive or weedy species of *Drosophila.* One is a rigid chromosomal polymorphism which serves to fix a general-purpose genotype (Carson, 1965). Flies of such species are able to survive under a variety of ecological conditions but are not specially adapted to any particular niche. The term "Jack-of-all-trades-but-master-of-none" (Baker,1965) can be used. In contrast, the other mechanism involves largely monomorphic chromosomes with a very labile response to a variety of selection pressures. While they do not possess the general purpose genotype, such species are able to adapt to a wide variety of environments, becoming more specialized in the process. On the basis of mutant studies and linkage information, as summarized by Craig(1967), *A. aegypti* seems to show considerable genic polymorphism, which rather points to the second adaptive type of mechanism. An answer to this question could be a prime objective for further cytogenetic studies in *A. aegypti.*

Adaptation (in the genetic sense) is a response to environmental pressure. Increased survival of adapting, or genetically preadapted individuals, will cause a genetic shift in the level of adaptation in their population. We are already so familiar with genetic adaptation to insecticides that never again are we likely to express the same confidence in a chemical that we once expressed for DDT. There are, however, other ways in which a population might adapt to control measures that are more subtle than the development of resistance to chemicals. Behavioral changes relating to adult feeding and resting patterns, the development of exophily for example are well known (Mattingly, 1962). In *A. aegypti* an apparent shift to tree-hole breeding occurred during the Trinidad eradication scheme (Kellet and Omardeen, 1957) and was tentatively attributed to a repellent action of the BHC applied to the more normal larval sites. The existence of a similar potential in the United States was recognized soon after (Porter *et al.,* 1961), and recently Schliessman (1966) has documented breeding in leaf axils of bromeliads in Florida.

If we assume that breeding in these exceptional or abnormal sites has actually increased shortly prior to its reported occurrence, this change could represent a natural extension or colonization of an introduced species into new habitats. Alternatively, the change could have been a recent response to a new environmental pressure. The failure of *A. aegypti* to extend its breeding to tree holes or plant axils in its first two hundred or more years in the United States would seem rather surprising, but not without precedent in other colonizers. A mutation or influx of new immigrants could have provided the necessary alteration in genetic potential as in the case of *Solenopsis saevissima* (Brown, 1961.) is the second possibility, response to a new environmental pressure, any more plausible? Since larval sites reflect adult oviposional behavior, let this be reexamined in the light of possible genetical and behavioral interactions that might effect the population dynamics.

If attractive breeding sites develop high larval densities, the resulting mortality may more than nullify the egg production of the excess ovipositing females. This could represent a natural check on population growth, but it would not allow the full exploitation of the habitat, since other, less attractive, sites might not have been visited. It would seem that a tendency of a female to seek alternative sites to those which were crowded would be of selective value, not only to the progeny of that female but also to the population as a whole. There would be greater survival among the larvae in the site she rejected.

In both the field and laboratory *A. aegypti* shows a peak in its diel rhythm of oviposition during the late afternoon (Haddow and Gillett, 1957; McClelland, 1960). This may represent no more than the optimal period for visual or olfactory location of small bodies of water, nevertheless this same activity peak also serves to bring a maximal number of ovipositing females together at one time. The density of ovipositing females at the breeding sites, rather than the overall density of the species in the total habitat, may be a critical factor in the self-regulation of the population. Ovipositional activity, synchronized by a circadian rhythm, mught thus be an *epideictic* phenomenon as suggested and defined by Wynne-Edwards (1962). In other words interaction between females at potential breeding sites could be a mechanism on the one hand limiting oviposition at any site in relation to density, and on the other promoting further site searching and the utilization of a wider range of breeding sites.

Woke (1955, and personal communication, 1967) has observed in laboratory colonies that crowding may inhibit oviposition in various arthropods, but it is not clear whether this represents interference in the cage as a whole or in a restricted part of it such as an oviposition site. The important result of ovipositional interference in nature would be that a shortage of preferred breeding sites might lead not so much to reduced breeding as to the utilization of abnormal sites. Thus it does seem that an environmental pressure such as the removal of preferred breeding sites could lead to behavioral modification. Some aspects of this problem are currently under investigation in the laboratory at Davis.

One part of the operational plan of *A. aegypti* eradication in the United States is community environmental sanitation (Schliessmann, 1966), since most of the preferred breeding sites of *A. aegypti* are undesirable articles of junk or refuse. An added bonus of this source reduction activity is its social value in community clean-up. Breeding sites not removed are sprayed at intervals. Public education may reduce, but is unlikely to prevent, a steady input of potential breeding sites into the habitat between times of spraying. The effect of source reduction is thus to increase the ratio of the number of new, unsprayed sites to that of the old sprayed sites remaining. Even if the total number of breeding sites is less, a higher proportion of them will be unsprayed. A gravid female will thus have a greater probability of ovipositing in a clean site. The reduction in total numbers of containers on the other hand may, by the mechanism outlined above, encourage oviposition in unusual breeding sites such as plant axils. Any tendency for *A. aegypti* to be repelled by insecticide applied to potential sites would enhance both effects still further.

Without data from sophisticated field experiments there can be no denial that a clear risk exists that current operational techniques in *A. aegypti* eradication may actually be promoting a behavioral change in breeding habits. At the same time the effect of the control measures will not only reduce the overall numbers of *A. aegypti*, it will fragment previously extensive panmictic populations into several discontinuous demes with a higher rate of inbreeding. Such a situation was recognized early in the classic work of Sewell Wright (1932) as one favoring intergroup selection and providing one of the best opportunities for evolutionary change. Genetic assimilation of initially behavioral adaptations might be expected to occur readily in such a milieu. The occurrence of a situation permitting or encouraging intergroup selection in *A. aegypti* would be interesting since intergroup selection is the controversial cornerstone of the Wynne-Edwards hypothesis (Wynne-Edwards, 1965; Wiens, 1966).

The demonstrable success of present control methods in effecting a reduction in populations of *A. aegypti* must not lull us into false optimism. We may in fact be creating, unobtrusively, strains of the species more intractable to eradication than those presently under attack. The danger will be particularly great if a fall-off in the momentum of the eradication campaign were to allow populations with altered behavior to increase. The paradoxical remedy seems to call for an increase rather than a decrease in the number of breeding sites, and the treatment of all of them with a chemical that will kill larvae without repelling oviposition. This may not have the local political value of community clean-up, but biological considerations should come first.

It is increasingly becoming realized among biologists that forcing an animal population, and I feel particularly that of a highly plastic, weedy species, into a low density phase can bring about compensatory changes at many levels that favor its survival. The possibility of such density effects occurring in mosquitoes as a normal phenomenon has received little if any attention. Now is an opportune moment.

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VEHICLE MOUNTED ASPIRATORS

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ABSTRACT

A description is given of a jeep and garden tractor-mounted aspirator. Resting mosquitoes which took flight when disturbed by the approach of the aspirator were captured but ground litter was not disturbed by the low air velocity. The effect of air temperatures on collections is discussed. Data is presented to show that vehicle aspirators are particularly useful when blood engorged mosquitoes or samples more representative of all gonotrophic stages are desired.

ACTIVITY AND SEQUENCE OF MOSQUITO PREDATORS IN WOODLAND POOLS IN ONTARIO

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Abstract

This paper gives data additional to those reported earlier on the occurrence, populations, and habits of water beetles that are predaceous on univoltine, aedine mosquitoes in southern Ontario. A new type of aquatic trap was used to follow the diurnal movements of the beetle at different depths in vernal pools and also in a permanent pond. Of 30 species of aquatic animals collected in the vernal pools, 16 were Dytiscidae, 2 Hydrophilidae, and 2 were fish. The number of predaceous beetles in mid-June averaged from 4.7 to 5.6 per sq. yard in small pools and 2.7 in a large pool.

Trap catches showed that, in general, the predators were more active at night than during the day, and more active near pool margins than at the surface or on the bottom.

The occurrence of the predators in relation to mosquito development appears to follow an annual pattern. Some species come out of hibernation earlier than others and their immatures are present for different periods. There is evidenec that predaceous beetles from vernal pools overwinter in permanent waters, but leave them in early spring (April) to return to the breeding pools. Late in the summer, when the vernal pools are about to dry up, some species return to permanent water.

PRELIMINARY OBSERVATIONS ON THE INCIDENCE AND BIOLOGY OF A MERMITHID NEMATODE OF *AEDES SOLLICITANS* IN LOUISIANA

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ABSTRACT

During the last six months of 1966, large populations of *Aedes sollicitans* collected in southwest Louisiana were found parasitized with the mermithid nematode *Agamomermis culicis*. Seventeen percent of the adult females sampled were infected; the parasitism ranged from 0 to 91 percent in individual populations. Parasitism occurred equally in both sexes.

Eggs of *A. culicis* hatch upon flooding and preparasitic nematodes enter by penetrating the integument of the host larva. The nematode matures only in the adult mosquito. Upon maturation, the postparasitic juvenile escapes from the adult mosquito, molts to the adult form, copulates and lays eggs in 14-21 days at room temperature. Eggs mature in 9-14 days.

No lethal effects from the nematodes were observed in fourth instar and pupal stages of *A. sollicitans*. *A. culicis*, when present, prevents egg development in *A. sollicitans* and usually kills the host upon emergence. When female *A. sollicitans* do survive the emergence of the nematode, they may develop an egg batch, but the number of eggs appears to be about half that of an uninfected female.

Parasitism of other species of mosquito by *A. culicis* occurs in the laboratory but appears to be lethal at a very early larval stage or host resistence prevents development of the parasite.

FLUCTUATIONS IN DISTRIBUTION AND ABUNDANCE OF *AEDES VEXANS* (MEIGEN) IN SALT LAKE COUNTY

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In 1956 the South Salt Lake County Mosquito Abatement District expanded inspection procedures into an extensive larval survey. The purposes of the study (Graham 1959) were: (1) To obtain information that will aid in predicting unusual increases in mosquito larval populations; (2) to determine long term trends in mosquito populations that cannot be determined by adult populations remaining after control operations; and (3) to obtain greater knowledge of larval habitats preferred by each species.

The study has shown changes in distribution and abundance of several species within the district. This paper considers significant increases in populations of *Aedes vexans* (Meigen) during the past four years of the study as compared with earlier years of the study.

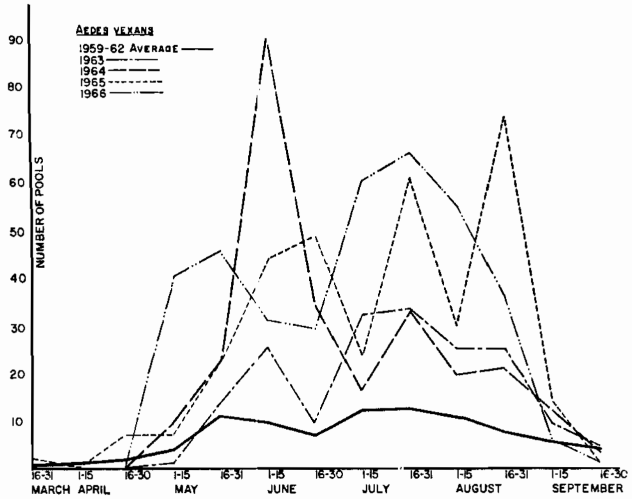

Figure 1 – Seasonal distribution of pools wth larvae of *Aedes vexans* in South Lake County, from 1959 through 1966. Note: 1959 through 1962 are averaged.

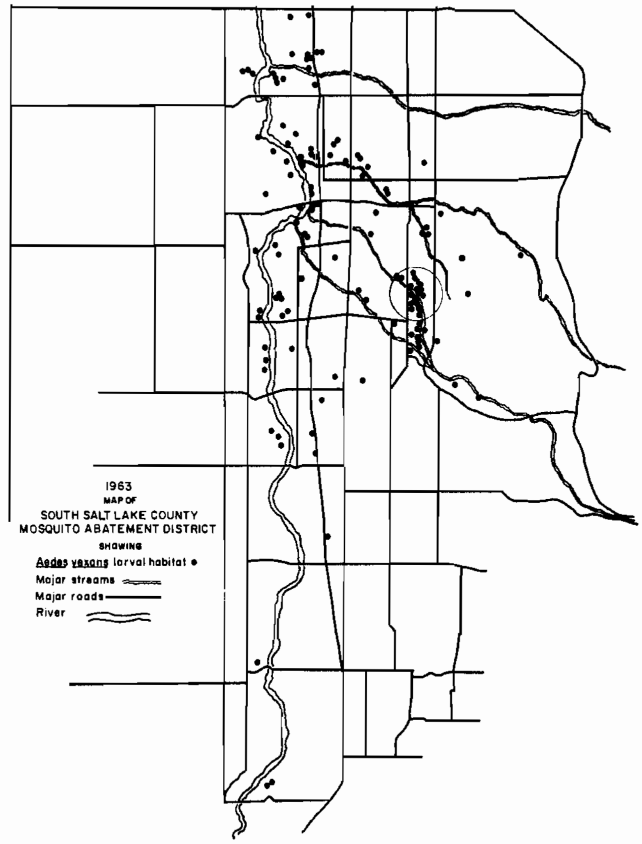

Figure 3 – Map of South Salt Lake County showing distribution of pools producing *Aedes vexans* in 1963. Circle denotes area of unusually high production. of *Aedes vexans* in South Salt Lake County, from 1959

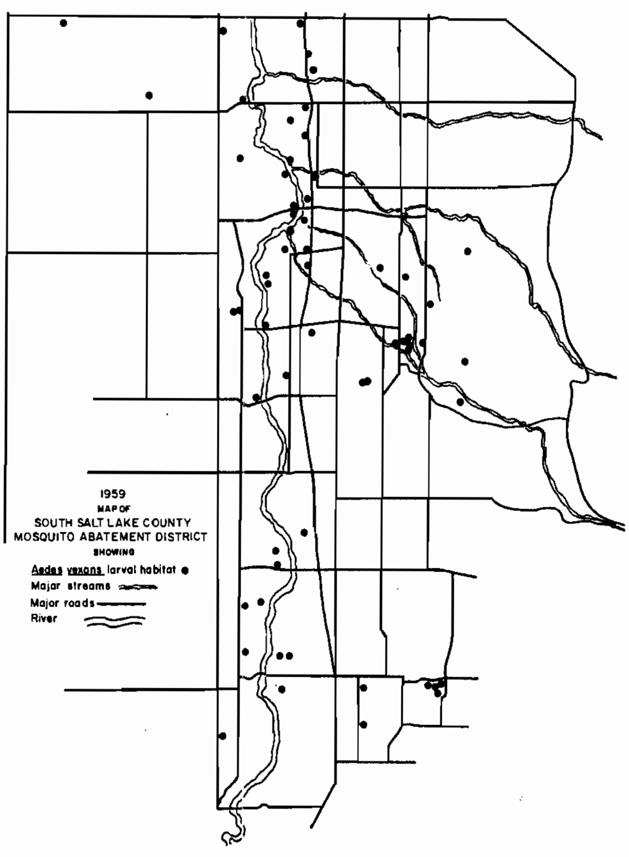

Figure 2 – Map of South Salt Lake County showing distribution of pools producing *Aedes vexans* in 1959.

The first three years of the expanded survey are not included here because this period of time was necessary to adequately standardize procedures. However, data collected concerning *A. vexans* populations is essentially the same from 1956 through 1962.

Inspectors for the district are required to collect a sample of larvae from each pool where they are found and record certain data. The data applicable to this paper are date and location of pool. The larvae are later identified in the laboratory.

In *Mosquitos of Utah,* Nielsen and Rees (1961) report *A. vexans* as a multibrooded species occurring principally in overflow pools near streams in the lower valleys and commonly appearing in pools created by irrigation. In August, 1938 (Rees, 1939), a severe migration moved into Salt Lake City from the southern areas of the county now controlled by the South Salt Lake County Mosquito Abatement District. Graham, Rees and Nielsen (1958) reported *A. vexans* decreasing to a point where only minor, localized annoyances were occurring. They stated, "Permanent control measures have considerably reduced the larval habitat of *A. vexans* and it is no longer an important control problem in Salt Lake County." Mosquitos taken in New Jersey light traps also indicated low numbers of *A. vexans* in the county.

Light trap and larval survey records showed little change in either numbers or distributions of this species in the county until 1963. In that year a significant increase occurred in the number of pools producing this species and in the distribution of the species in the district each subsequent year has shown a greater increase (Fig. 1). By plotting on a map the pools that produced *A. vexans* during the year (Figs. 2, 3, 4) the distribution can be shown. The year 1959 (Fig. 2) is representative of the four-year period from 1959 through 1962. The year 1963 (Fig. 3) shows the first significant increase and 1966 (Fig. 4) shows current distribution.

Pools that produce larvae of *A. vexans* in Salt Lake County generally produce the species only once during the year, although they may produce several broods of other species. In the first four years of the study period, 1959 through 1962, 88% of the pools producing *A. vexans* produced this species only once. During the last four years this average dropped to 74% (Fig. 5).

The effect of an increase in the number of pools producing more than one brood of *A. vexans* on the number of positive inspections of this species is shown in Figure 6. Figure 6 also shows that the increase in larval populations of this species has been continuous for the four-year period.

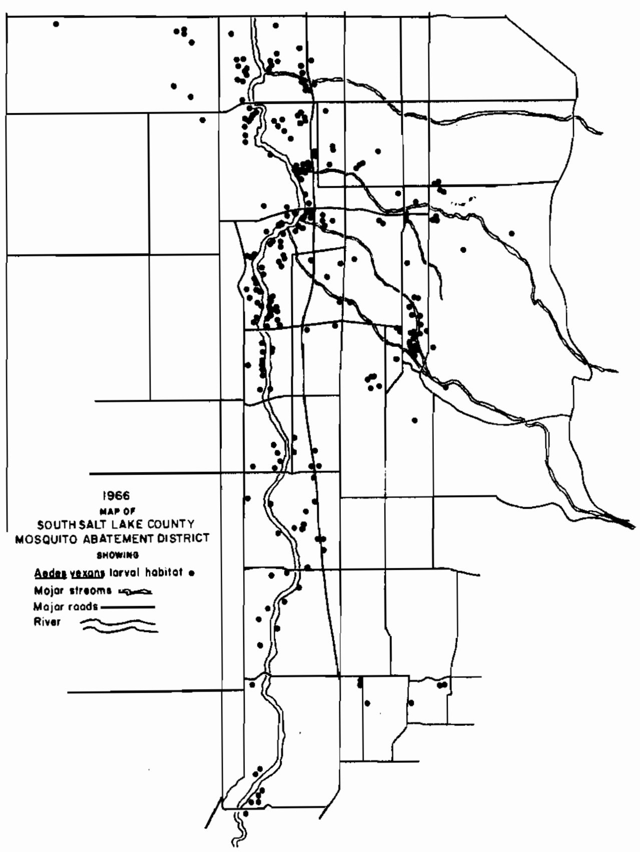

Figure 4 — Map of South Salt Lake County showing distribution of pools producing *Aedes vexans* in 1966.

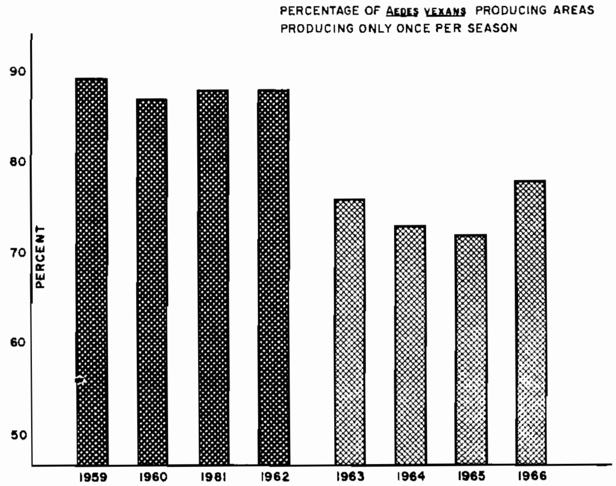

Figure 5 — Comparison of percentages of *Aedes vexans* producing areas producing only once per season, from 1959 through 1966.

The increase of *A. vexans* larval habitats is the result of the mosquito moving into sources which previously had not produced this species. In the first years of the study, *A vexans* was found typically in flooded pools along streams or irrigated areas in or close to shade. During the past four years of the study, pools with *A. vexans* have been found in this typical habitat but they have also been found in other areas. For example, there have been significant increases in pools with this species along the Jordan River, in many cases at considerable distances from any shade.

The factors responsible for these changes in *A. vexans* populations have not been completely determined. The four years when *A. vexans* increased in number were years of relatively high precipitation and the others, particularly 1961, were years of low precipitation. However, the changes in abundance correlate poorly with precipitation. Changes of patterns of water usage throughout the county probably have more effect. The growth of human population in the district has been rapid and extensive and has occurred principally in areas which produce the largest numbers of *A. vexans.* As the areas change from irrigated farmland to suburban dwellings, the water used for irrigation has to go elsewhere, frequently creating new larval habitats. An example of changes in water management causing increases in *A. vexans* populations occurred in 1963 along Little Cottonwood Creek at about 1000 East and 6000 South. A potentially high *A. vexans* producing area existed along this stream where there are a large number of trees along an old stream-bed area left dry by rechanneling the stream for flood control. This area pastured a few cattle and horses, but little irrigation or flooding took place until 1963 when the land was leased for pasture and the number of cattle was increased substantially. The farmer proceeded to irrigate the area periodically and large numbers of *A. vexans* adults emerged before the pools were discovered. Distribution of the pools is shown circled on the 1963 map (Fig. 3).

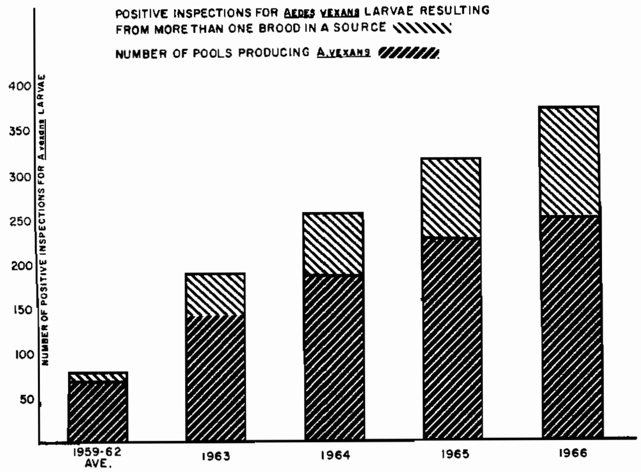

Figure 6 – Comparison of the number of positive inspections for *Aedes vexans* with the number of pools producing this species, from 1959 through 1966.

The area around this problem has become increasingly urbanized and *A. vexans* became enough of a nuisance to warrant corrective measures being taken by the farmer at the suggestion of the district. Resulting decreases are evident in 1964, '65, '66. This demonstrates the need to obtain knowledge of mosquito habitats and convince the public of the value of water management. As land is taken out of farming and converted into subdivisions, the water that was used for irrigation becomes excess and finds its way in increasing quantities into the streams coming from the canyons and into the Jordan River which functions as the main drain in Salt Lake County. This causes some increases in flooding along these streams and results in more *A. vexans* habitats.

Data available at this time does not explain why such a small percentage of the pools produce *A. vexans* more than once. Sometimes production is as high as six times a year but most pools produce only once. There is no seasonal pattern of distribution of sources that would account for this.

Summary

Extensive larval surveys in Salt Lake County, Utah, from 1959 through 1966, have shown increases in the number and distribution of positive inspections for *A. vexans* larvae during the past four years. The factors responsible for the increase have not been completely determined but possible increases in precipitation and water available for irrigation, along with changing water uses due to urbanization, are probably the major causes. Since the increased distribution of *A. vexans* larval habitat is in areas where they were not found previously and which are not typical of their larval habitat in Salt Lake County, perhaps the species is making an adjustment to a decrease of their normal habitat.

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TRAPPING MOSQUITOES WITH SOUND

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Abstract

Sounds varying in frequency from 180-350 Hz and back in one minute attracted male *Aedes stimulans* (Walk.) from a swarm when the source was placed below it. The optimum intensity appeared to be in the range of 50-70 dB in the swarm. Males were not attracted by the same intensity if the source was placed above or at a distance from the swarm. The catches of a New Jersey and a suction trap baited with the sound were compared over 12 nights.

Forty-three percent of the males caught over this period were in the sound trap (477:635); however this trap seldom caught any other insects whereas even at the peak of the season, male mosquitoes were outnumbered by about 8:1 by other insects in the New Jersey trap.

At present this method of attracting males is not sufficiently effective to use in trap-sterilize-release procedures, but the technique is promising and may well be highly effective when more is known of the factors that influence swarming.

BENEFICIAL EFFECTS OF RESEARCH TO MOSQUITO CONTROL OPERATIONS

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The South Salt Lake County Mosquito Abatement District has conducted some research programs every year since the district began operations. This paper will not report results of the research program because they have been and will be reported elsewhere. We wish to take this opportunity to discuss the benefits, some direct and others indirect, to control operations resulting from research activities.

One of the simplest of the projects, classed for district purposes as research, is the field testing of new insecticides. The data from this program enables the district to switch to more economical or effective compounds with a minimum of confusion and also permits the development of safe techniques under controlled, rather than field conditions when more toxic insecticides are required.

The district has tested various types of granules since 1953 and reported the results in various journals, including *Mosquito News* and the *Proceedings of the California Mosquito Control Association*. The most satisfactory granule for our purpose is sand core and we like to think that our interest, along with that of many other district and agencies, contributed in some small way to the development of this type of granule by industry.

Each district has its own peculiar problems, and procedures that are ideal for one will be less so for another. Sand core granules were ideal for the particular problems in South Salt Lake County and their extensive use resulted in savings of eight to ten thousand dollars per year. Without a testing program and the continuing search for new materials and techniques the district would have eventually changed to granules but with such a program the change occurred much sooner.

The insecticide testing program, as mentioned above, is a simple project and cannot be defined as research in the strictest sense. Other projects in the district are more complex and represent sophisticated research procedure. An example is our study of mosquito larval populations and the factors that influence them. For this project the district employs, on a part-time basis, a statistician and a limnologist from the University of Utah as well as some technicians. Large volumes of data have been collected, coded, and placed on IBM punch cards. The cards are then sent through a computer, either the IBM 7040 at Brigham Young University or the Univac 2000 at the University of Utah. A computer program for our district's problems has been developed by the faculty at Brigham Young University.

Data obtained from this program has allowed the district to adopt a special inspection schedule for *Aedes nigromaculis* that has proved to be extremely effective. If the same type of schedule were used for all species and all sources the cost would be prohibitive for the district, but normal procedures for other species gives unsatisfactory control for *A. nigromaculis*.

This program also provides the basic data for the surveillance program for western equine encephalitis. Details of this program, which has been in operation for several years, were published in *Mosquito News* in 1964.

Inspectors for the district, generally graduate students from the University of Utah, collect data for the research program. This data is collected during the regular inspection and experience has shown that the collection of data not only does not reduce the amount of inspection but makes inspection more complete. Morale among workers is better and the research data can be used to maintain better control over the activities of the workers.

Each inspector is given a number and it is possible to make a number of comparisons between inspectors and determine work patterns if the computer is programmed to give such information. Such data can be of great value to an administrator in evaluating workers and making assignments.

Another research project involves insecticide residues and the ultimate fate of toxicants introduced into the environment. Electron Capture Gas Chromatography is used in the study. So far from this project the district has determined the cause of a number of control failures, has adjusted spraying procedures for specific situations, changed granular formulations for more effective control, and developed information to demonstrate that they cannot be held responsible for residues of insecticide in many aquatic environments.

Another advantage of a research program is its value in attracting better summer employees. The prospect of being involved in a research program is attractive to students seeking summer employment and allows the district to select better personnel.

Conclusion

Properly designed research projects in local mosquito control agencies can make significant advances in our knowledge and improve control operations more than enough to pay the cost of the research program.

EXPERIMENTS ON THE BIOLOGICAL CONTROL OF MOSQUITOES WITH THE FUNGUS *Beauveria bassiana* (Bals.) Vuill

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Abstract

The ability of the fungus, *Beauveria bassiana*, to kill the larvae, adults, and eggs of mosquitoes has been tested. Experimental hosts included *Culex tarsalis*, *C. pipiens*, *Anopheles albimanus*, *Aedes aegypti*, *A. sierrensis*, and *A. nigromaculis*.

The infective units of the fungus, conidia or spores, were found most effective in killing larvae when they were applied as a dust to the surface of the water. This was explained by the fact that the primary sites of invasion were the perispiracular lobes of the larval siphon.

During May and June of 1966, the mortality of *C. pipiens* larvae in outdoor test ponds ranged from 70% to 95% at a dose rate of three pounds of viable spores per acre. The *Anopheles* and *Culex* larvae tested all proved to be susceptible to the fungus while the *Aedes* larvae were not.

In laboratory tests against the adults of *C. tarsalis*, *C. pipiens*, *A. aegypti*, *A. sierrensis*, *A. nigromaculis*, and *A. albimanus* spores of *B. bassiana* produced 100% mortality within five days after exposure, while less than 50% mortality occurred in corresponding controls. Outdoor tests against the adults of *A. nigromaculis* in screen cages were less successful, yielding only 58% mortality. In this case, the fact that adults rested on the screen walls of their test cages, rather than in the dusted grass that had been provided, may explain the low mortality.

Eggs of *Culex* and *Aedes* exposed to the spores of *B. bassiana* hatched normally.

LABORATORY OBSERVATIONS OF AEDINE MOSQUITO OVIPOSITION (DIPTERA, CULICIDAE, *AEDES*)

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AND

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For several years we have been concerned with a study of oviposition site selection by salt marsh *Aedes* mosquitoes (Knight and Baker 1962; Knight 1965, 1967; and McGaughey and Knight 1967). A portion of this study has involved an examination of the pre-oviposition behavior of the gravid female. During this work a need became apparent for a knowledge of the body movements typical of a gravid *Aedes* female preparing for and carrying out oviposition. The study reported here was accomplished in response to this need.

In contrast to those genera (such as *Anopheles, Culex, Culiseta,* and *Uranotaenia*) which oviposit on water surfaces, most *Aedes* mosquitoes routinely lay their eggs on moist solid substrates in locations which will subsequently be flooded. Two principal situations are utilized as oviposition sites by the members of this mosquito genus: container habitats such as tree holes and plant axils, and moist soils just above the water line of drying flood pools.

Considering the size and importance of the genus *Aedes*, relatively few descriptions have been reported of the oviposition act by aedine mosquitoes. Agramonte (in Howard, Dyar, and Knab 1912), Christophers (1960, 504), Fielding (1919), and Wallis (1954a) all have descriptions of varying quality of the act of oviposition by *Aedes aegypti* (Linn.). Wallis (1954a 1954b) described the egg-laying of *A. polynesiensis* Marks and *A. pseudoscutellaris* (Theobald). However, all of these aedine species are container breeders (subgenus *Stegomyia*) and differ basically from the flood-water species (such as the subgenera *Aedes, Aedimorphus,* and *Ochlerotatus*). For this latter group, no published observations have been found. Nielsen and Nielsen (1953) described an observation of gravid *A. taeniorhynchus* females coming nocturnally to road and ditch pools but the mosquitoes were not actually seen to oviposit.

We are indebted to Dr. W. H. McGaughey for designing and building the oviposition observation box employed in this study and for providing the colonized mosquito species used.

METHODS AND PROCEDURES

Experiments were performed using the following species: *Aedes (Aedimorphus) vexans* (Meigen), *A. (Finlaya) triseriatus* (Say), *A. (Ochlerotatus) canadensis* (Theobald), *A. (Ochl.) fitchii* (Felt and Young), *A. (Ochl.) stimulans* (Walker), *A. (Ochl.) taeniorhynchus* (Wiedemann), *A. (Ochl.) trivittatus (Coquillett)*, and *A. (Stegomyia) aegypti* (Linneaus). However, complete data were obtained only for the last three. Gravid individuals of *A. aegypti* and *A. taeniorhynchus* were obtained from laboratory colonies. The remaining species were brought directly from the field.

The field specimens were obtained by allowing blood-seeking females to feed upon the collector. When their feeding was completed, they were captured with an inverted test tube and placed in cylindrical quart-size, paper ice cream cartons with a lid at each end. The bottom lid contained a gauze pad saturated with distilled water. The top lid was screened with 16-mesh screen wire. Daily a pledget of cotton saturated with a 5% sugar solution was placed on top of the screen wire. To insure maintenance of a high relative humidity, each carton was held in a closed plastic bag.

All of the field-collected individuals were held at room temperature until they were thought to be ready to lay eggs. *A. vexans* and *A. trivittatus* had digested their blood meal by about 79 hours after receiving it, but the other field species (*A. triseriatus, A. fitchii, A. canadensis,* and *A. stimulans*) required about 103 hours to digest theirs. *A. aegypti* and *A. taeniorhynchus* were reared in a constant temperature cabinet at 29 C. These two species were fed either on humans or on guinea pigs, and respectively were ready to lay eggs 48 and 72 hours after feeding.

Except for *A. aegypti*, oviposition activity in all of these species is initiated by the onset of darkness. In order that egg-laying observations could be made during the day, the light-dark cycle of *A. taeniorhynchus* was changed so that darkness occurred in the period of 1-9 p.m. Since the light-dark cycle of the field-collected adults could not be safely changed, egg-laying observations for them began around 7 p.m. Observations of oviposition by *A. aegypti* were made during the day at whatever time full gravidity was believed to have occurred.

Shortly before the time of expected oviposition, the mosquitoes were immobilized with cold. The mesonotum of each adult was then attached with bayberry wax to a wire loop mounted in the end of an applicator stick, using the technique described by Feir, Lengy, and Owen (1961).

The applicator sticks were mounted vertically in holes drilled in a section of wood which in turn was suspended over a gauze pad oviposition site at just sufficient height to permit the tethered mosquitoes to rest their tarsi in a normal position on the pad. Five mosquitoes were used for each experiment. The gauze pad substrate was saturated with distilled water. This entire apparatus was then placed in a small closed container termed an "oviposition observation box (OOB)." This box was about 10 inches square and 8 inches deep and had a stereoscopic microscope set into one side so as to permit horizontal rather than vertical viewing. To permit the entrance of sufficient light so that oviposition might be observed, a small circular opening was cut in the wall opposite the microscope. By directing this opening towards a window, the lateral viewing in silhouette of tethered mosquitoes in the act of oviposition could be observed.

The five mosquitoes mounted for an experiment were each observed every 15 minutes by pushing the block bearing the oviposition sites and the mosquitoes across the field of focus of the microscope. When a mosquito was found in the act of oviposition, observations were confined to this one individual until it ceased to lay eggs. During the observations, a description of all movements made by the ovipositing female was recorded. The period of observation for each experiment averaged about two hours, but the tethered mosquitoes were kept in the OOB until the next day to insure sufficient time for the laying of a complete batch of eggs. The number of eggs laid by each observed mosquito was then counted and its abdomen was dissected to see if any mature eggs were left unlaid. The experiments were conducted under room conditions. Temperatures averaged 28 C. (range 25-31 C.) and relative humidities 92% (range 50-97%) In all, slightly more than 100 hours of observation were involved.

Results

Oviposition observations were attempted with all of the previously mentioned species of *Aedes*, but adequate data were obtained only for *A. aegypti*, *A. trivittatus*, and *A. taeniorhynchus*.

Extent of Oviposition. Extensive observations of oviposition behavior were obtained for 10 females of *A. aegypti*. These females laid a total of 537 eggs with an average of 54 eggs per female. The actual laying of 242 eggs was observed. Upon dissection of the females following oviposition, it was found that they had in every case laid all of their eggs, probably indicating that the experimental procedures did not in themselves inconvenience oviposition by this species.

Oviposition by nine individuals of *A. taeniorhynchus* was observed. Of the total of 509 eggs laid by these females, the actual deposition of 84 was observed. Upon dissection it was found that only 60% of the mature eggs had been laid. This was believed to indicate that this species didn't adapt to the artificial egg-laying conditions imposed upon them nearly as well as *A. aegypti*.

In seven completed observations of oviposition by *A trivittatus*, 73 out of 482 eggs were observed being laid. Dissection disclosed that 70% of the mature eggs had been deposited. As with *A. taeniorhynchus*, this is probably an indication that the species didn't adapt very successfully to the artificial conditions of the experiments.

One female of *A. fitchii* laid all of its eggs in the OOB, and nine of these were observed being laid.

Modification of Abdomen for Oviposition. The female of *A. aegypti*, under normal conditions, has nearly the basal half of abdominal segment seven and all of the tergum of segment eight retracted into the preceding segment. However, for the act of oviposition these two segments were fully extended, the remainder of the cerci was exposed, and the postgenital plate came into view. A similar extension of the abdomen in preparation for oviposition occurs in *A. trivittatus* and *A. taeniorhynchus*. These two species differ from *A. aegypti*, however, in that segment eight is completely retracted during the nonovipositing poise and in that it is noticeably slenderer and more tubular than it is in *A. aegypti*. This difference represents a basic distinction between the subgenera *Ochlerotatus* and *Stegomyia*. The ovipositor-like structure of the terminal portion of the aedine abdomen has been illustrated by Marshall (1938, 72) and by Belkin (1962, II: 408).

In all cases the actual laying of an egg was first detected by the full extension of the telescoped segments and by an increase in their diameter caused by the movement of the egg through them. In *A. aegypti*, preceding the appearance of an egg, there were often straining movements. These consisted of a repeated extension and closing of the posterior abdominal segments or the bending of the posterior segments to a 90 degree angle with the remainder of the abdomen. *A. taeniorhynchus* was also observed extending and closing the abdomen but here the movement was not necessarily followed by egg laying. The abdomen of *A. trivittatus* had a longer and more tapered appearance than that of *A. aegypti* or *A. taeniorhynchus*. It also appeared to be more flexible, as was revealed by the unusual extent to which the tip could be bent and by the speed with which it changed positions.

Deposition of Eggs. In *A. aegypti* the flat side of the egg was dorsal when it emerged from the tip of the abdomen; whereas in *A. trivittatus*, *A. taeniorhynchus*, and *A. fitchii* the convex side was. According to Craig (1956) the more flattened side in all these species is morphologically the dorsal in respect to the developing larva. In contrast to this, Christophers (1960, 132) stated that in *A. aegypti* the flattened side is in this respect ventral.

The eggs of *A. aegypti* were frequently laid directly to the rear of the abdomen in even horizontal stacks. This was also observed in *A. trivittatus* and *A. taeniorhynchus*, but not nearly as frequently. This method was aided in *A. aegypti* by the fact that its eggs were very sticky (also reported by Christophers 1960, 504) and adhered to one another, while the eggs of *A. taeniorhynchus* were only slightly sticky and those of *A. trivittatus* not at all.

With *A. aegypti* the column of eggs at times became so high the mosquito's abdomen couldn't reach high enough to place another egg on it. In such a case the female would kick the eggs with her hind legs or push them away with her abdomen. Although laying eggs in even columns seemed to be the usual way for tethered females of *A. aegypti*, it was not the only way. Eggs were frequently laid without a definite pattern but just in a cluster directly behind by dropping them on the substrate or by laying them down on it. The eggs of *A. taeniorhynchus* and *A. trivittatus* were generally laid in a similar random manner.

In depositing eggs directly on the substrate, *A. aegypti* usually accomplished this with a wiping movement, done by starting with the abdomen fully extended and drawing it forward along the substrate. *A. trivittatus* was also observed doing this.

All three species were observed laying their eggs in front of them. These mosquitoes, however, were generally individuals mounted with their abdomens pointing vertically downward and couldn't comfortably extend backwards and still reach the substrate. When *A. taeniorhynchus* and *A. trivittatus* laid their eggs in front of themselves, they often pushed down on the substrate with the sixth abdominal segment, allowing the tip of the abdomen to be bent forward and the eggs to be laid with the eighth segment and cerci bent slightly above the substrate.

All three species were observed laying a few eggs upright on the substrate, but none of the species inserted their eggs directly into the wet gauze substrate. However, this was probably because of their tethered condition, since it is definitely known that *A. taeniorhynchus*, when free, does insert eggs several layers deep in gauze, provided water does not close the interstices. *A trivittatus* laid some eggs by first lowering the abdomen to the substrate after an egg had already appeared and then immediately raising her abdomen and dropping the egg onto the substrate. *A. fitchii* was observed laying eggs in a pile with the eggs lined up vertically upright in the substrate. This wasn't observed with any other species. The eggs of *A. taeniorhynchus* often stuck to the tip of the abdomen. This was also observed with *A. aegypti*, and sometimes the immdeiate appearance of one or two more eggs caused two or three to be laid at a time as they would stick together end to end. Both species would then remove them by bobbing their abdomens, rubbing them against the substrate or egg pile, or brushing them off with their hind legs.

Ovipositing females of *A. aegypti*, *A. taeniorhynchus*, and *A. trivittatus* were frequently observed feeling their eggs with the tip of the abdomen with a curious "sniffing" motion which Christophers (1960, 504; speaking specifically of oviposition by *A. aegypti*) compares to the manner in which an elephant uses its trunk. This type of behavior especially occurred when the individual was laying eggs in stacks, since it aided in what was apparently a conscious effort to position the eggs. Infrequently, females of all three of these species were observed blowing a small bubble from the tip of the abdomen.

Additional Body Movements Coincident with Oviposition. The oviposition behavior of *A. aegypti* was marked by much body movement. The abdomen was always probing around the substrate or eggs; the cerci and postgenital plate frequently made movements resembling the opening and closing of a mouth; all six legs moved often, but especially the hind pair; the tarsi of the hind legs were rubbed together, especially when eggs became stuck to them; frequent escape-type movements were observed; at times all legs would move in a walking-type motion; and the proboscis frequently bobbed up and down. Occasionally, the tip of the abdomen was rubbed with the hind tarsi.

All of these types of movements were observed for all three species, but especially for *A. aegypti*. In all three species the proboscis was often down in the substrate and eventually a clear spot would appear in the anterior part of the abdomen, indicating that the individual had been drinking from the substrate. Although sometimes there were no auxiliary movements to indicate that drinking was taking place, occasionally when the proboscis was in the substrate the head would be seen to bob slightly, the palpi moved forward slightly, and there would be occasional pumping movements of the abdomen.

In addition to the movements just described, *A. taeniorhynchus* was observed pumping the two metathoracic legs frequently. After laying an egg this species would also sometimes rub the tibial apices of hind legs either together or along sides of the abdominal apex. In an observation of an untethered female of this species, the individual was seen to rub the anterior wing margins (wings in resting position) with the femoral-tibial area of the hind legs. Then, the female turned the wings down along the body and rubbed their upper surfaces with the hind legs. Following this, another egg was laid.

The cerci of *A. taeniorhynchus* are distinctly elongate and when a female abdomen was moving side to side and backwards and forwards with the sniffing-like motion previously described, it was noticed that the cerci were often spread finger-like and that their apices served as contact points with eggs or with the substrate.

Oviposition Behavior of Other Aedine Species. *A. triseriatus*, *A. vexans*, and *A. canadensis* laid eggs in the OOB, but their oviposition acts were never observed. Some eggs of *A. vexans* were found inserted as deeply as the fourth layer of the gauze substrate. *A. fitchii*, *A. triseriatus*, and *A. canadensis* laid their eggs four days after obtaining their blood meal, while it required three days or less for *A. vexans*, *A. aegypti*, *A. trivittatus*, and *A. taeniorhynchus*. *A. stimulans* would not lay eggs even though females had digested their blood meal by the fourth day. They appeared to be gravid, which would seem to have eliminated the need for another blood meal, but apparently the species didn't adapt at all to the artificial oviposition environment.

Discussion

As far as known, the observations reported here are the first made microscopically. An additional advantage was the capability to observe mosquito oviposition from a lateral aspect, where all phases of the act were readily apparent. Tethering the females, of course, made for a highly artificial situation, and this must be kept in mind in attempting to extrapolate from these observations to what actually occurs in the field.

At least in the case of *A. aegypti*, it seems from the observations of Christophers (1960, 504) that lack of mobility would only partially handicap oviposition by that species. Whereas he reported that the female shortly before oviposition moved about in a restless manner, once oviposition began as many as 20 eggs would be laid without a change in position. He observed females isolated in specimen tubes and provided filter paper slips for oviposition sites.

A. aegypti will in the laboratory occasionally lay eggs directly on the water surface. In such case, it has been reported by Agramonte (in Christophers 1960, 504) that the ovipositing female walked about on the water surface between the deposition of each egg. Even when laying eggs on solid surfaces, *A. aegypti* apparently moves frequently, since it very commonly lays its eggs in lines along natural creases. Kennedy (1942) suggested that the fidgeting exhibited by *A. aegypti* in his laboratory tests was probably prolonged owing to the smooth edges of the dish used and the necessity to walk and flit about until a suitable edge was found.

The most explicit description of oviposition by *Aedes aegypti* was published by Wallis (1954b). Mentioned there was the observation that deposition of an egg by an untethered female was accomplished by a combination of abdominal movement from side to side and of a walking movement as the mosquito ranged sideways and forward over the surface.

Although characteristic body deformations and movements accompany egg deposition in aedine mosquitoes, it was disappointing to find that no actions were noted which could be used as indicators of whether or not a proffered substrate was suitable for an oviposition site. This is in contrast to gustatory reception where a downward movement of the proboscis of a mosquito in tarsal contact with a solution can be used as an indication that the solution has been found satisfactory for imbibition (Feir, Lengy, and Owen 1961). Perhaps indicator movements can be found when untethered mosquitoes are observed. Such a study is planned.

This study was accomplished in the Department of Zoology and Entomology, Iowa State University, Ames, Iowa, in connection with studies supported by NIH Grant AI-05119 and by the Undergraduate Research Participation Program, NSF (GE6349).

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INHERITED SEMI-STERILITY IN *AEDES AEGYPTI*

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ABSTRACT

A reciprocal translocation induced by gamma radiation has been successfully carried in a strain of *Aedes aegypti* for over 25 generations. Since the interchange involves the male-determining chromosome it appears only in the heterozygous condition in all male progeny. The egg fertility associated with this aberration is approximately 30%. This suggests a possible variant of the sterile-male technique for biological control of this species. Competitive studies indicate the new strain to be as vigorous and fecund as are normal strains. Experiments are continuing to ascertain if successive releases of these translocated males into natural populations might prove to be means of population control.

EGG LAYING HABITS OF THE DEER FLY *CHRYSOPS DISCALIS* WILLISTON, IN MARSHES BORDERING THE GREAT SALT LAKE, UTAH

A. BRUCE KNUDSEN AND DON M. REES
Institute of Environmental Biological Research
University of Utah — Salt Lake City, Utah

During the past three summers a field study has been conducted on biting tabanids in the marshes bordering the eastern shore of Great Salt Lake, Utah. The study area, formerly inundated as recent as 1872 by waters of Great Salt Lake, is now utilized for limited agricultural purposes or as developed marshlands. The marshlands have been created by man-made earthen dikes which impound waters from the Jordan River drainage system. With the development of these extensive marshes the production of noxious insect pests such as mosquitoes, gnats, deer flies and horse flies has increased. The abundance of these pests and potential disease vectors in these marshes which are adjacent to the most densely populated area in Utah, is an incentive for conducting this study. This report on the oviposition habits of *Chrysops discalis* Williston is part of a more extensive study now in progress in this area on the biology and control of tabanids.[1]

During this study, six species of tabanid flies have been collected in the study area. These flies in order of their abundance and importance as pests are: *Chrysops discalis* Williston, *Hybomitra sonomensis* Osten Sacken, *Tabanus punctifer* Osten Sacken, *Tabanus productus* Hine, *Chrysops aestuans* van der Wulp, and *Chrysops fulvaster* Osten Sacken.

Chrysops discalis was selected for this study as it is the most abundant and important tabanid species

[1] This project is supported in part by funds provided by Research Grant No. 12-14-100-8070 (33), Agricultural Research Service, Entomology Research Division, United States Department of Agriculture.

in thees marshes. This study was conducted in an attempt to determine the egg laying habits of this species, first in existing situations in the marshes, and second on sites prepared to induce egg laying. In the existing habitat an attempt was made to determine the kind of situations selected by the flies for oviposition. The factors considered are: species of plants on which the eggs are laid and the density of plant cover where oviposition occurs; and number of egg masses deposited in relation to water depth and distance from shore.

The procedure followed in the natural egg laying study consisted of systematically examining the vegetation in and near the water where the larvae of this fly occur. Meter square quadrats at intervals of five paces were used in this survey. Vegetative cover was classified from zero to one hundred percent in each quadrat according to density standards of one to five with twenty points in each of the five increments. Egg clusters were counted in each quadrat on each species of plant.

The egg laying sites were prepared by placing wooden laths upright at twenty foot intervals. The laths extended from high ground on one side of the open ponds to the high ground on the opposite side. This survey became a productive method of obtaining large numbers of deer fly eggs. The survey also provided data pertaining to the relative abundance and variations in the population of *C. discalis*. The procedure followed was to count the number of egg clusters on each lath and approximate the number per mass. Following the completion of the count each lath was scraped clean of eggs. Factors such as distance of lath from shore, water depth, water and air temperatures and time of day when the eggs were deposited was determined.

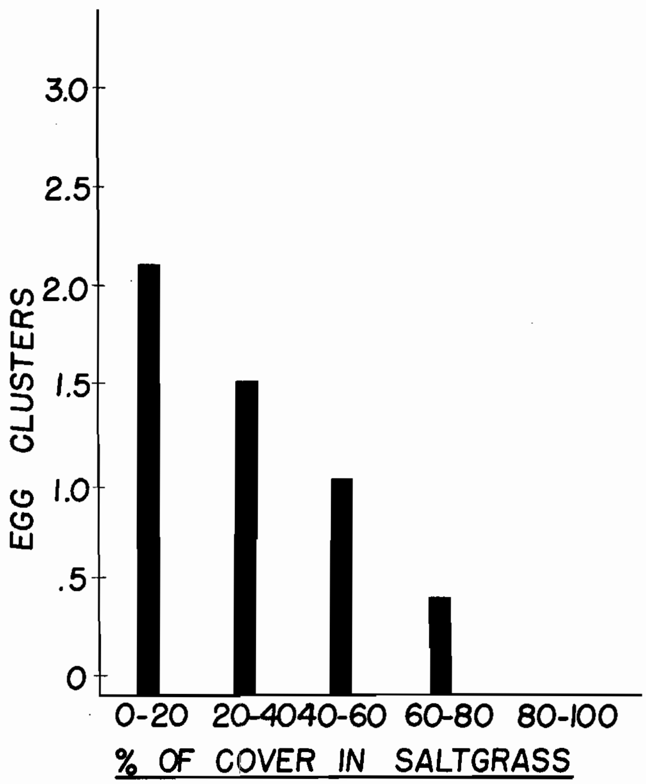

Figure 1 — Average No. of *C. discalis* egg clusters per meter sq. quadrate correlated with % of cover in saltgrass.

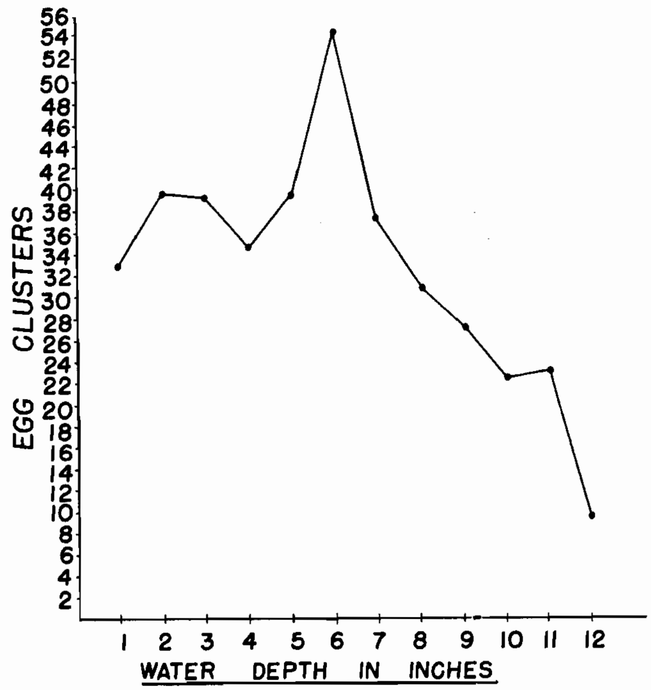

Figure 2 — Average No. of *C. discalis* egg clusters on laths compared with depth of water at which oviproduction occured.

Egg masses of *C. discalis* were observed upon eleven plant species: *Distichlis stricta* (Torr.) Rybd. (Saltgrass); *Scirpus acutus* Muhl. (Hard stem bulrush), *Scirpus paludosus* A. Nels. (Alkali bulrush); *Scirpus olneyi* A. Gray (Olney's bulrush); *Typha angustifolia* L. (Narrow leaf cattail). *Typha latifolia* L. (Common cattail); *Atriplex patula* L. (Atriplex); *Salicornia rubra* A. Nels. (Salicornia); *Allenrolfea occidentalis* (S. Wats.) Kuntze (Pickleweed); *Sarcobatus vermiculatus* (Hook) Torr (Greasewood); and *Tamerix gallica* L. (Tamarisk). The eggs were laid over water ranging from one to eleven inches in depth.

Figure 1. shows the distribution of egg clusters on saltgrass in relation to the density of the plant cover.

During the 1966 season, a total of 39,295 egg clusters were counted on the laths. These egg masses varied in number from 100 to 600 eggs. The laths were located in water varying in depth from one to twenty-four inches. The greatest distance from shore at which the laths were located was three hundred feet.

Figure 2. shows the correlation between egg laying and water depth as determined in four study areas.

Figure 3. depicts the correlation between oviproductivity on prepared egg laying sites with the distance the laths were located from shore.

Daily egg cluster counts were conducted on the laths prepared as egg laying sites. Figure 4. shows the weekly variations in the number of egg clusters deposited by *C. discalis* in a study area during the 1966 season.

Conclusions

1. A total of eleven common species of marsh plants were found to be utilized as natural egg laying sites.

2. *C. discalis* apparently are not plant specific in their egg laying habits but readily oviposit on any type of vegetation or other objects present above suitable water.

3. Saltgrass is utilized most frequently for egg laying, this may be attributed to the abundance of this plant species in the marshes compared with other species on which eggs are laid.

4. Egg laying of *C. discalis* in natural vegetation was observed in densities ranging from zero to eighty percent with the favored densities occurring between zero and forty percent. In most cases observed, egg clusters were deposited upon plants which are separated from other emergent plants by several inches of open space.

5. Egg laying of *C. discalis* in the marshes of the study area was observed only over water or above soil which was saturated with water.

6. Egg laying was observed to occur at temperature of 66° F. or above.

7. It was noted that the site of previously laid egg masses attracted egg laden females seeking a site for oviposition.

8. A positive correlation exists between the place of oviposition and distance from shore as tested by Chi square analysis. As the distance from shore increases, egg laying decreases.

9. A positive correlation was also found between oviproductivity and water depth. The favored depth approximates six inches.

10. No correlation was found to exist between number of egg masses and quantatative numbers of adult female flies. This conclusion is based upon the observation that many females when disturbed during oviposition selected another site to resume egg laying.

11. Oviposition ceases when the water is removed from an area; egg laying resumes when the locality is re-flooded.

12. Eggs were found on the laths during the period from May 13, to September 30, 1966. The peak in oviproduction occurred during the week of June 10, 1966.

13. Fom the study to date it seems possible that applied water management may be used to substantially reduce the number of *C. discalis* produced on these marshes without materially altering existing marshland habitat.

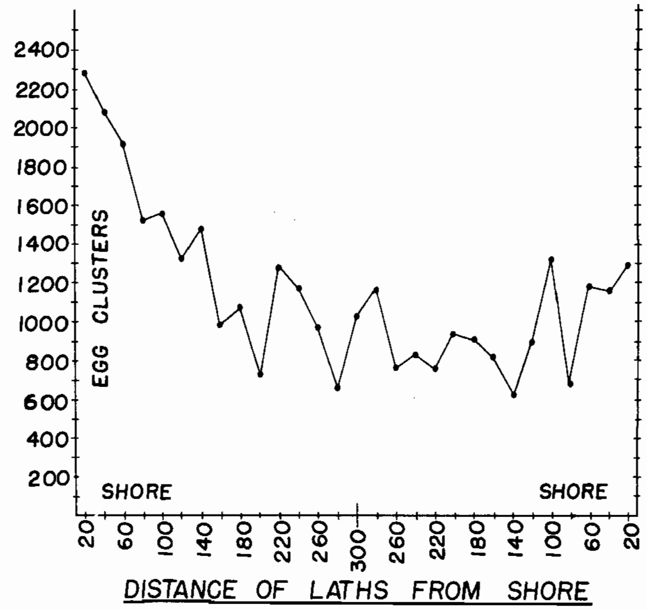

Figure 3 – Egg laying of *C. discalis* on laths correlated with distance from shore.

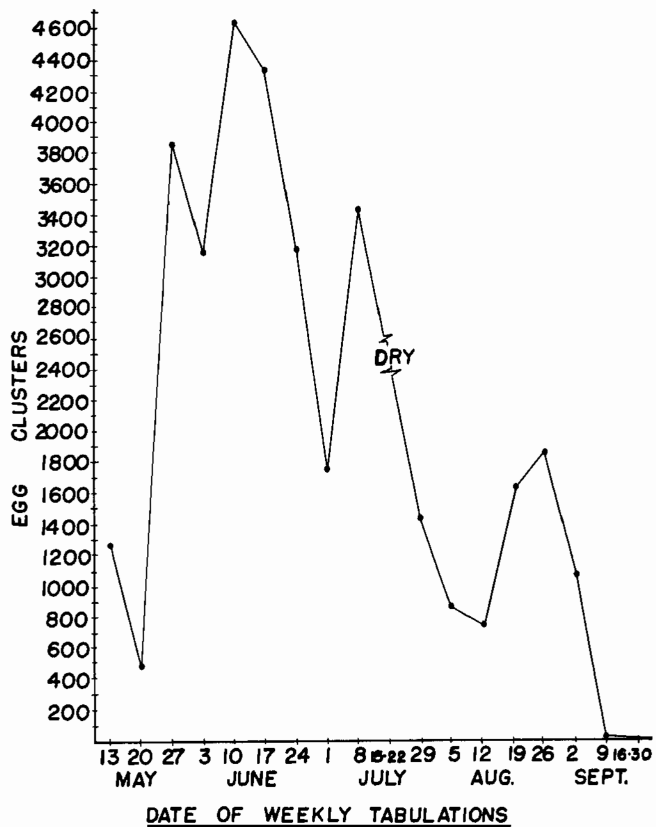

Figure 4 – Variation in the number of egg clusters deposited by *C. discalis* in a study area during 1966.

NEW METHODS OF INTRODUCING VISUAL AND AUDITORY CUES

J. S. Haeger

Florida State Board of Health

Entomological Research Center, Vero Beach, Fla.

ABSTRACT

Many failures in attempts to colonize mosquitoes are due to inadequate simulation of natural situations for mating. It is apparently not enough to experiment only with cage size, light cycles, and light chores.

A very large cage is not the answer to the problem of refractory species; if used, special lighting effects, as described below, are still required. We have found that cages from 18″ cubed to 48″ cubed (for the very strong flyers) can be used if 1″ to 2″ black stripes are provided on the ceiling and floor of the cage for flight orientation.

Two independent phases of light are involved, the light coming through the translucent ceiling, simulating sky-glow, and the general room illumination, simulating ambient illumination. The latter, in the present experiments, involved evening and morning twilights, of 45-minute duration for convenience in studying responses. About 20 minutes past sunset and before sunrise the ceiling illumination became brighter than ambient lighting and provided the mosquitoes with a striped silhouette for flying by while the floor, lighted by lights in back of the cage, provided striped markers for ground speed control (optomotor effect). This orientation situation is then maintained throughout the night phase of the diel. During the "dark" of the night, the room ambient light is kept at 0.02 to 0.03 Lux while a low light burns above the false ceiling of white fiberglass panels. The effect is somewhat like moonlight passing through a haze, so that a soft light permeates the room and cage interior.

A more tangible visual aid has been the introduction of tree branches inside the cage. These provide two types of markers, as some species fly above them while others fly in the spaces between the branches.

Aedes taeniorhynchus respond to all these cues or markers, flying in the cage below the ceiling strips or above the tree branches. *Aedes infirmatus* seem to fly and mate between the branches.

Shading a portion of the cage ceiling, 8″ along two sides, tended to concentrate the flight of *Culex nigripalpus* under the central striped area. Pairs in copula would then not intercept the cage sides, resulting in immediate release of the female, but flew instead in zigzag fashion between or across dark and light areas.

It was found that all the above visual aids were still not enough to obtain mating in *Culex nigripalpus* and *Culex salinarius.* Apparently the sounds of certain other mosquito species sharing the cage with them in some way stimulated more mating. *Aedes taeniorhynchus gave the most* consistent results as a contributor of this extra sound.

By the third generation of selection, in the two above *Culex* species, sound stimulation by another species was no longer necessary. Details of our methods in the use of interspecific sound stimulation will be published elsewhere.

SUBMITTED PAPERS SESSION

CONCURRENT

TUESDAY, FEBRUARY 7, 1:30 P.M.

HARRY D. PRATT, *Presiding*

TRAINING ASPECTS OF THE UNITED STATES SPONSORED *AEDES AEGYPTI* AND MALARIA ERADICATION PROGRAMS

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National Communicable Disease Center, Atlanta, Ga.

During the last four years the National Communicable Disease Center of the U.S. Public Health Service has been given responsibility for two major programs dealing with mosquito-borne diseases: the *Aedes aegypti* Eradication Program in the United States, Puerto Rico, and the Virgin Islands beginning in the fall of 1963, and the Malaria Eradication Program, formerly administered by AID, the Agency for International Development, beginning in the spring of 1966.

Although these programs deal with different species of mosquitoes, similar types of instruction, training literature, and visual aids were used in classes for both programs, when instruction included adult and larval mosquito identification, biology, survey methods, insecticides, spraying equipment, personnel management, and equipment maintenance. The malaria eradication students also received additional instruction in parasitology, the epidemiology of malaria, and the use of drugs.

The subjects covered by these courses and the training literature include:

1. *Identification of mosquitoes,* both adult and larval stages, including the yellow fever mosquito and associated species in the vast area from Hawaii through southern United States to Puerto Rico and the Virgin Islands, where the *Aedes aegypti* Eradication Program is in progress; and the major vectors of malaria in the 17 countries where the malaria eradication program is in progress or planned. Materials to aid training for both programs have been developed, including pictorial and illustrated keys dealing with the mosquito vectors of the various states and countries, supplemented by programmed-type booklets to help students learn about basic morphology of adult and larval stages of these mosquitoes.

2. *Biology.* In the *Aedes aegypti* training, particular attention is devoted to three biological traits of the yellow fever mosquito that have made the eradication concept a reality: (a) eggs are laid and the larvae develop only in water-holding containers, not in swamps, streams, or other natural water; (b) this mosquito has a short flight range – only about 100 yards, or the distance of about a city block; and (c) the species has a preference for feeding on human blood and living close to man. Much time is spent teaching the concept that the eggs of *aegypti* can remain unhatched on the walls of containers for many months, sometimes for more than a year, and that apparently negative neighborhoods may, in fact, have infestations in the form of dry containers with eggs that can hatch following the first heavy rain. In the malaria training, much time is devoted to such key items in the biology of major vectors as larval breeding places, flight range, and host feeding preferences. In particular, the training emphasizes the concept that there are several opportunities to kill the female *Anopheles* mosquito resting on surfaces sprayed with insecticide between the time she sucks up blood with malaria parasites and the time she can become infective and pass the *Plasmodium* on to another person.

3. *Surveys.* On the *Aedes aegypti* program, standard techniques for making larval surveys are taught as the best means of determining actual breeding places and pinpointing areas requiring treatment. Premises and block indices, based on the number of premises with yellow fever mosquito larvae, have long been used as important criteria of the status of *aegypti* eradication programs. On the malaria program, methods of making adult surveys – whether of the house, window-trap, or biting-collection type – are taught because of their usefulness in connection with operations and evaluations. A new type of survey tool still being evaluated on the *aegypti* program is the oviposition trap. These traps are black jars of water each containing a little "paddle" on which the yellow fever mosquito readily lays her eggs. The percent of positive jars in a survey area provides an index of the adult population present.

4. *Insecticides.* On both programs, DDT is the standard insecticide: 1.25% for the *aegypti* program and 2.5% for the malaria program. However, alternate insecticides such as malathion are also used where DDT resistance is a problem. Relatively new insecticides are being used on an experimental basis – Abate in rain barrels and dichlorvos in houses and cisterns. Much time in classes is devoted to methods of formulating and applying these insecticides and to teaching safety precautions.

5. *Equipment.* Instruction in proper use and maintenance of the compressed-air hand sprayer is common to both programs. In addition to this, training on the *Aedes aegypti* Eradication Program stresses the proper use and maintenance of the power spraying equipment necessary to spray large accumulations of actual and potential breeding places of the yellow fever mosquito, such as the stirrup pump, which is used in some tropical areas.

In addition to these subjects common to both programs, much time in the malaria courses is devoted to parasitology, epidemiology, and drugs. Following the curricula established at the Jamaica, Manila, Lagos, and Lome malaria field training stations, a considerable portion of the courses has been spent in teaching correct methods of making, staining, and diagnosing blood films for the detection of malaria parasites. Much time is also devoted to the epidemiology of malaria, with emphasis on the difference in the habits and housing of people, in the ecology of the vectors, and in climatology throughout the vast tropical and subtropical area where the program is in progress.

In the United States, training classes have made effective use of the following NCDC-produced motion pictures:

1. Biology and Control of Domestic Mosquitoes, M-357, 22 minutes
2. Enemy in Your Home, M-911, 13 minutes
3. The *Aedes aegypti* Inspector, M-1151, 23 minutes
4. The Front Line of the Battle, M-1070, about 15 minutes
5. It Must Be the Neighbors, M-1161, about 13.5 minutes
6. Field Recognition of Mosquito Larvae, M-1272, about 5 minutes
7. Let's Finish the Job, M-1373, about 10½ minutes

Copies of these films are available on free, short-term loan to interested individuals and organizations.

LABORATORY AND FIELD STUDIES ON MOSQUITO CONTROL IN WASTE DISPOSAL LAGOONS IN LOUISIANA

C. D. Steelman, J. M. Gassie and B. R. Craven
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Department of Entomology, Baton Rogue, La.

Abstract

The toxicity of several insecticides to bacterial populations in waste disposal lagoons was compared at five concentrations. Dursban (*O,O*-diethyl *O*-(3, 5, 6-trichloro-2-pyridyl) phosphorothioate) and naled caused the highest levels of mortality to the bacterial populaiton having LD_{50}'s of 0.028 and 0.02%, respectively. Abate (*O,O,O′,O′* - tetramethyl *O,O′* - thiodi-*p*-phenylene phosphorothioate) and fenthion with LD_{50}'s of 0.9 and 0.66%, respectively, caused the lowest mortality. Bacterial mortality as low as that found in tests using 0.0001% (1 ppm.) concentrations would probably not cause a functional disruption of the lagoon process. The daily addition of fecal material along with bacterial development in a lagoon could offset the bacterial mortality caused by insecticide application at 1 ppm. or less to control mosquito breeding.

The determination of effective procedures for controlling the southern house mosquito, *Culex pipiens quinquefasciatus* (Say), an important vector of St. Louis equine encephalitis breeding in waste disposal lagoons are presented. Several selected insecticide materials were shown to be highly effective in controlling this mosquito vector. Dursban provided 144 days of 100% larval control when applied at 1 ppm. to the total volume of lagoon water. The establishment of baseline susceptibilities of untreated natural populations of this mosquito species provides information which allows close observation on the potential development of resistance. The most toxic materials tested were Dursban (LD_{50}=0.000135, LD_{90}=0.00068) and Abate (LD_{50}=0.00054, LD_{90}=0.0012). Spraying the surface margin of the lagoon to a distance 3 feet out from the bank with a 3 gallon hand-pump sprayer provided the most economical and efficient method of application, giving 100 percent larval mortality within 24 hours.

MOSQUITO CONTROL AGENTS DERIVED FROM PETROLEUM HYDROCARBONS — LABORATORY EFFECTIVENESS

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University of Texas Medical Branch, Galveston, Texas
and
G. Chambers
Esso Research and Engineering Co., Baytown, Texas

Abstract

One hundred and ten hydrocarbons derived from petroleum were evaluated against the eggs, larvae and pupae of the southern house mosquito *Culex fatigans* (Wiedemann) and the yellow fever mosquito *Aedes aegypti* (L.), using six different test procedures, Fifty-six of the test materials ranged from two to eight times as effective as the No. 2 diesel fuel standard against larvae. Twenty-five of the oils produced 100 percent mortality in *C. fatigans* pupae when applied at the rate of 5 gallons per acre. Twenty of the hydrocarbons exhibited a greater residual effect than the standard, and twenty-five were faster acting than the control.

The test materials were generally more effective against the aquatic stages of *C. fatigans* than those of *A. aegypti*. The two test procedures involving the water surface application of oils to containers of larvae and pupae were found to be the most satisfactory for routine evaluation of the materials.

CONTROL OF MOSQUITO LARVAE WITH DURSBAN INSECTICIDE APPLIED AS A THERMAL FOG

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Plant Science Research and Development
Dow Chemical Company, Wayside, Miss.

Abstract

During the summer of 1966, field tests were conducted in Brazoria County, Texas, comparing Dursban with recommended chemicals for control of mosquito adults and larvae when applied through a thermal fogging unit. Applications were made using a Leco 120 thermal fog generator operated in a standard manner using 40 gph of finished oil mix.

As an adulticide Dursban at .02, .023 and .026 lb/A gave 90, 100, and 98 percent control, respectively, of caged *Aedes* adults. These rates compare favorably with naled at .021 lb/A and malathion at .15 lb/A as adulticides.

As a larvicide Dursban at .005 lb/A, the lowest dosage used, was effective. Control of larvae was not obtained with either malathion or naled applied at recommended dosages.

In five out of six experiments, Dursban at .023 lb/A gave 100 percent control of larvae in containers spaced at 50-foot intervals and located at distances as far as 700 feet downwind from the fog source. In the exceptional case, 100 percent control was obtained in the first 350 feet with percent control decreasing at the greater distances. Climatic conditions for fogging were undesirable at time of application.

SOME FACTORS AFFECTING KILL OF THE STABLE FLY, *STOMOXYS CALCITRANS* (L.), WITH INSECTICIDAL THERMAL AEROSOLS

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West Florida Arthropod Research Laboratory, Panama City

Abstract

Tests of naled in ground thermal aerosol against caged adults of the stable fly, *Stomoxys calcitrans* (L.), illustrated certain basic principles of the aerosol method for control of insects. A formulation containing 1¾ oz. actual naled per gallon of diesel oil gave only 70 per cent kill when applied over a swath of 300 feet at 40 gallons per hour, vehicle speed of 5 miles per hour. The kill with this formulation and operation was 89 per cent when the volume was increased to 80 gallons per hour.

This larger dosage of naled was then kept constant by applying 40 gallons per hour of a formulation containing 3½ oz. of naled per gallon, vehicle speed of 5 miles per hour, and by applying the 3½ oz. formulation at 80 gallons per hour, 10 miles per hour. There was no statistical difference in kill between any of the treatments where the larger dosage of naled was applied. It was concluded that, within the limits of speed and volume used in these tests, the most important factor affecting kill was dosage, i.e., the amount of actual naled applied per acre. However, the maximum and minimum limits of speed and volume for effective kill with this dosage were not determined by these tests.

Tests of a sublethal dosage applied to caged flies along three parallel streets showed a significant and progressive increase in kill on the second and third streets owing to increased dosage that resulted from drift of the aerosol from the preceding swaths. These results lend firm support to the effectiveness of the aerosol method for killing flying insects at distances far beyond those attainable with methods that utilize larger droplets. This is important in situations where swaths must be 600 feet or more owing to lack of access roads.

The tests showed that the mere visible presence of insecticidal fog in a target area does not assure satisfactory kill. For good kill of insects with aerosols, an effective dosage of the toxicant must be applied, as with other methods of insecticide application.

This research was supported in part by Contract No. 12-14-100-8184(33), U.S.D.A.

EVALUATION OF THERMAL AND NONTHERMAL FOGS AGAINST FOUR SPECIES OF MOSQUITOES

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Aedes aegypti Eradication Program, Savannah, Ga.

Abstract

In field tests of Baygon, Dursban and naled at Savannah, Georgia, against caged *Anopheles albimanus, Culex quinquefasciatus, Aedes aegypti* and *Aedes taeniorhynchus*, Baygon and naled were inferior to Dursban at 2 oz./gal. and only the latter approached malathion (6 oz./gal.) in efficacy. *C. quinquefasciatus* and *Aedes aegypti* were harder to kill than *A. albimanus*. No differences were detected between thermal and nonthermal fogs or between oil solutions and water emulsions.

ECOLOGICAL FACTORS INFLUENCING THE EFFICACY OF MOSQUITO CONTROL IN IRRIGATED PASTURES IN CALIFORNIA

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California State Department of Public Health
Bureau of Vector Control, Fresno, Calif.

Abstract

The gradual development of insecticide resistance in mosquitoes in California has been associated primarily with the selective action of treating *Aedes nigromaculis* in irrigated pastures. However, unexpected failures in control efforts cannot always be attributed to resistance. In many cases environmental factors can have a profound influence upon the success or failure of a chemical application.

Early season conditions such as lower temperature, better water quality, and better soil intake rates may aid chemical application; while increased plant growth, increased soil saturation, reduced evaporation, irrigation combined with rainfall, and cattle grazing over wet soil all tended to increase the mosquito production potential and reduce careful inspection application of insecticides. Meteorological conditions such as wind will both aid and hinder successful treatment with chemicals and can lead to erratic results.

Mid-summer conditions are even more complex. Irrigation timing, application rates, quantity of water applied, sources of water and water quality all contribute to operational and chemical failure. Even such

indirect factors as the price of beef and the availability of upland grazing will change field conditions sufficiently to interfere with the application of insecticides and the interpretation of need for treatment.

Late season conditions have the most critical influence on the efficacy of control. Soil intake rates are reduced, ponds are growing larger, new areas are provided protective cover for surviving pupae, irrigation water is being diverted to pastures from other crops, water quality may be reduced resulting in an increase in salinity, and adult mosquitoes will no longer drift into adjacent fields where crops have been harvested, but will disperse into greener areas such as school yards or communities. Increased soil temperatures tend to elevate water temperatures while increases in humidity may reduce evaporation.

Many new areas within fields will contribute sources of surviving mosquitoes that will be difficult to locate even under the best conditions. These control failures contribute largely to next year's populations of mosquitoes.

It is apparent, therefore, that many factors in the environment contribute to the success or failure of control operations and indirectly lead to the development of surviving populations of mosquitoes that may have been selected for insecticide resistance.

INSECTICIDE TOLERANCE IN *CULEX TARSALIS* LARVAE IN CALIFORNIA

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ABSTRACT

Insecticide resistance in larvae of *Culex tarsalis* Coq. has been known in California since DDT resistance was recorded by Gjullin and Peters in 1952 (Mosquito News 12:1-7). Organochlorine compounds are now rarely used against the species, having been gradually replaced by organophosphorus insecticides during the 1950's. Parathion, methyl parathion, fenthion, and malathion are now the principal compounds employed against *C. tarsalis* in California.

Operational problems have been encountered by mosquito control agencies in using each of the common organophosphorus chemicals against *C. tarsalis*. The insecticide resistance surveillance program of the State Department of Public Health, which has been in operation since 1963, has included testing larvae of *C. tarsalis* in both controlled and uncontrolled areas against the several compounds. Mean lethal (LC_{50}) values for parathion, methyl parathion, and fenthion vary from .0007 to .0095 ppm. The range of each is less than ten fold, and there is no indication thus far of high levels of tolerance. From this evidence there is no clear indication that resistance has developed against any of the three compounds.

Some levels of tolerance are high enough so that they might cause operational problems, however. Specific field observations of failures, coupled with larval tolerance tests are lacking in the case of *C. tarsalis*, but some of the sporadic control problems with parathion, methyl parathion, and fenthion may be due to the development of tolerance.

Several control agencies have reported *C. tarsalis* larval populations which have not yielded to normal applications of malathion. Malathion resistance in *C. tarsalis* from Fresno, California, was detected a decade ago (Gjullin and Issak, 1957, Mosquito News 17:67-70). Subsequent work on Fresno material (Plapp *et al*, 1961, Mosquito News 21:315-319; Matsamura and Brown, 1961, J. Econ. Entomol. 54:1176-85) showed the presence of a single gene, partially dominant for malathion resistance. Matsamura and Brown noted that a backcross of heterozygous resistance with homozygous susceptible *C. tarsalis* produced a mixture of two populations with a resultant plateaued regression line. Several of the *C. tarsalis* populations we tested showed similar patterns.

The malathion failure threshold for most control agencies approximates 0.1 ppm at the LC_{50} (Womeldorf, *et al*, 1966, Proc. Calif. Mosquito Control Assoc. 34:77-9). *C. tarsalis* larval populations which either showed an LC_{50} of at least 0.1 ppm or evinced a plateau in the regression line were considered to be resistant. Resistant populations were detected throughout the entire Central Valley from Tehama County south to Kern County. Lack of evidence of resistance along the coast and in Southern California may reflect inadequate sampling.

No adult tolerance testing was performed, but since resistance to malathion in adults is known to be linked with resistance in larvae, it is probable that widespread resistance in adult *C. tarsalis* occurs in California. With present evidence, however, it is not safe to conclude that malathion is no longer effective as a *C. tarsalis* adulticide.

THE INFLUENCE OF SUBLETHAL DOSAGES OF INSECTICIDES ON THE BASAL FOLLICLES OF *AEDES AEGYPTI* (L.)

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ABSTRACT

The larval stages of *Aedes aegypti* were reared in the presence of sublethal amounts of DDT, dieldrin, or malathion under controlled conditions of time of hatch, temperature, and food, and the effects on basal follicle number (BFN), oviposition, and egg hatch determined. The sublethal maximum levels (SL max defined as the maximum dosage at which there occurs mortality no greater than 0.1 per cent above that experienced by control populations) of DDT, dieldrin and malathion for newly hatched larvae are approximately 0.001, 0.001, and 0.0125 ppm, respectively. At such levels, the BFN of emerging adult females after 96 hours on sugar water was 14-29 percent greater than the controls. Part of this effect was due to ethanol, the insecticide dispersant. Increased BFN was proportionately greater in survivors of lethal levels and does not appear to be the result of selection for individuals with higher BFN. Although the effect generally did not extend below $SL_{0.75}$, results with malathion indicate that

the slope of the dosage/BFN response line may depend on the insecticide and may be related to slope of the dosage/mortality regression line above SL max. Although basal follicles may appear as early as the fourth instar, increased BFN was also observed when 3-day-old larvae were treated with their SL max DDT (0.003 ppm). Such results favor the hypothesis that insecticides and other toxic chemicals act as stress stimuli and indirectly cause maturation of rudimentary ovarioles, which normally do not mature or contain a basal follicle. Additional experiments indicated that increased BFN results in increased deposition of eggs having approximately the same hatchability as the controls. It appears highly probable that at least some insecticides, while controlling mosquito populations, induce survivors to rebuild populations more rapidly than expected.

CROSS-TOLERANCE OF CALIFORNIA *AEDES NIGROMACULIS* (LUDLOW) LARVAE TO EPN, ABATE AND DURSBAN

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Abstract

Insecticide resistance of the pasture mosquito, *Aedes nigromaculis* (Ludlow), has provided control problems for almost 20 years. The first control failures due to resistance in California were with DDT and were reported in 1949 by Smith (Mosquito Buzz 3:2). By 1951, the problem had extended to the other chlorinated hydrocarbon insecticides then in use (Gjullin and Peters, 1952, Mosquito News 12:1-7).

Substitution of the organophosphorus compounds was generally satisfactory until 1958, when resistance to parathion was verified by Lewallen and Brawley (California Vector Views 5:56). Since this time, resistance to both malathion and methyl parathion has been confirmed (Brown, *et al.*, 1963, Mosquito News 23:341-5). Presently, increasing reports of control failures using fenthion make a change to a new material imminent in certain areas where severe resistance problems have made obsolescent the previously effective materials.

In response to the needs of mosquito control agencies for early detection of resistance, routine laboratory testing of field-collected mosquito larvae was initiated in 1963 by the State Department of Public Health. A major portion of this program has been devoted to surveillance of susceptibility levels for populations of *A. nigromaculis*. In addition to determining relative susceptibility to the chemicals currently used, promising candidate materials have been evaluated. These materials have been tested against both resistant and susceptible populations from throughout the state in an effort to determine their relative effectiveness and the degree of cross-tolerance present. Three organophosphorus compounds, which have been extensively tested as possible substitute materials, are EPN, Abate® and Dursban®.

BIOLOGICAL ACTIVITY OF SURFACTANTS AND SOME CHEMICAL INTERMEDIATES AGAINST PRE-IMAGINAL MOSQUITOES

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Mosquito suppression programs in California depend primarily on larvicidal measures. Among these measures, the use of synthetic organic insecticides lead other efforts. The use of petroleum oils as larvicides is also relied upon in certain situations. Due to the rapid development of resistance in *Aedes nigromaculis* Ludlow to the most potent phosphate larvicides such as parathion and methyl parathion, new interest in the development of other types of mosquito larvicides is being generated. It is possible that having different modes of action than the organic phosphates may provide a reasonable solution to the phosphate resistance problem.

In order to evaluate the physico-chemical properties of petroleum oils for mosquito control, fundamental studies on the biological efficacy of these products were initiated. As one phase of this program, the biological activity of a variety of surface active agents, additives and several intermediates had to be ascertained against mosquito larvae. A large number of these compounds is available commercially or for experimental purposes. The potential use of these compounds for mosquito suppression has not been investigated. This paper presents a preliminary report on the activity of some of these materials against larvae of *Culex pipiens quinquefasciatus* Say. Some of the compounds evaluated manifested a high degree of biological activity against the larvae. These materials seem to have a different mode of action than the organic phosphates, and therefore, offer good possibilities for control of phosphate resistant as well as susceptible mosquitoes. Further research on the development of these materials as mosquito larvicides has to be accomplished before they can be used on a practical basis. A group of similar compounds showing exceptional activity were studied in detail (Mulla 1966, 1967), which look promising for the control of pre-imaginal mosquitoes.

Methods and Materials

Samples of the technical material of each compound were dissolved in acetone to prepare 1% solution on weight volume basis. Further dilutions if needed were made from the stock solutions. For biological assay aliquots of the acetone solutions were added to 100 ml. of tap water (PH 7.5–8.0) in 6-oz. waxed paper cups where 25 4th-instar mosquito larvae or pupae were placed. The procedure followed was similar to that for the screening of insecticides (Mulla et al. 1964). Mortality was assessed 24 hours after treatment. The materials were evaluated at a concentration of 10, 50, 100, and 200 ppm. For some of the materials the range of biological activity was determined and the LC_{50} and LC_{90} levels were determined.

Information on the chemical nature and other properties of the materials evaluated was obtained from the manufacturers or from a monograph on detergents and emulsifiers (Anonymous 1964). Some of this information is included in the tables presenting the data.

Results and Discussion

All the materials evaluated at 50, 100, and 200 ppm in these studies are divided into two groups. The first group of compounds showing no biological activity at 200 ppm concentration are listed in Table 1. A variety of nonionic, cationic, amphoteric and alkaline surfactants or intermediates showed no biological ac-

Table I

List of surfactants and other additives which manifested no biological activity at 200 ppm concentration against 4th-instar larvae of *Culex p. quinquefasciatus* in preliminary laboratory tests.

Supplier and material	Chemical description	Type[1]
Atlas Chemical Ind:		
G-1045-A	polyoxyethylene sorbitol laurate	NI
G-1087	polyoxyethylene sorbitol hepta-oleate	NI
G-1096	polyoxyethylene sorbitol hexa-oleate	NI
G-1186	polyoxyethylene sorbitol oleate	NI
G-1196	polyoxyethylene sorbitol oleate (higher ethylene oxide mole ratio than in G-1186)	
G-1255		
G-1256	polyoxyethylene sorbitol esters of mixed fatty and resin acids	
G-2081		
G-2083		
G-2085		
G-8916-P	polyoxyethylene sorbitan esters of mixed fatty and resin acids	
G-8916-T		
General Aniline & Film Corp:		
Igepal CO-880	nonyl phenoxy polyoxyethylene ethanol	NI
N-methyl-2-pyrrolidone	N-methyl-2-pyrrolidone	NI
2-pyrrolidone	2-pyrrolidone	NI
General Mills, Inc.:		
Deriphat 160-C	β-iminodiproprionate; partial sodium salt of N-lauryl	AMPH
Hodag Chem. Corp.:		
Hodag 40-0	polyoxyethylene glycol (400) monooleate	NIB
Hodag 60-L	polyoxyethylene gylcol (600) monococonate	NIB
Hodag 62-0	polyoxyethylene glycol (600 dioleate)	NIB
Hodag GTO	glycerol trioleate	NIB
Nopco Chem. Co.:		
Agrimul TL	aromatic sulfonate—oxide condensate blend	AN
Agrimul UL	nonionic-amionic blend	NIAN
Nopalcol 4-L	polyethylene glycol (400) mono laurate	NIB
Nopalcol 6-L	polyethylene glycol (600) mono laurate	NIB
Olin Mathieson Chem Co.:		
Monoethanolamine	2-aminoethanol	ALK
Diethanolamine	2, 2′-iminodiethanol	ALK
Triethanolamine	2, 2′, 2″-nitrilotriethanol	ALK
Retzloff Chem. Co.:		
CX-230	a polyoxyethylene lauryl ether	
D-40	a polyalkylene glycol ether	
D-50	a polyalkylene glycol ether	
FR-62	sodium salt of sulfonic acid	
FX-100	a dinonyl phenoxy poly (ethyleneoxy) ethanol	
FX-220	a dinonyl phenoxy poly (ethyleneoxy) ethanol	
L-775	a blend of alkyl aryl polyoxyethylene glycols and polymerized aromatic resins	
Retzloff Chem. Co.:		
NS-195-B	a polyoxyethylated vegetable oil	
NX-150	a nonylphenoxy poly (ethyleneoxy) ethanol	
NX-200		
NX-300		
NX-500		
RCC-50	a blend of alkyl aryl polyoxyethylene glycols and fatty acids	NI
SPONTO 60	polyoxyethylene-sorbitol—tall oil ester	
TALLEX 80	a polyoxyethylene ether	
TALLEX 120	a polyoxyethylene ether	
TALLEX 150	a polyoxyethylene ether	
Union Carbide Chem. Co.:		
Carbowax 200	polyethylene glycol	
Diethylene Glycol	diethylene glycol	
Wyandotte Chem. Corp.:		
Pluronic L-101	a condensate of ethylene oxide with a hydrophobic base formed by condensing propylene oxide with propylene glycol	NI

[1] AN = Anionic, ALK = Alkaline, AMPH = Amphoteric, B = Biodegradeable, NI = Nonionic, Cat = Cationic.

TABLE 2. Biological activity of various surfactants and other additives against the 4th-instar larvae of *Culex p. quinquefasciatus in* preliminary laboratory tests.

Supplier and material	Chemical description (R chain)	Type[1]	% mortality at conc. (ppm)		
			200	100	50
Armour Industrial Chem. Co.:					
Armeen L-7	beta amine (7 carbon)	CAT B	100	70	6
Armeen L-9	beta amine (9 C)	CAT B	100	100	88
Armeen L-11	beta amine (11 C)	CAT B	100	100	100
Armeen L-15	beta amine (15 C)	CAT B	100	100	100
Armeen L-15 acetate		CAT B	100	100	100
Armeen L-15 oleate[2]		CAT B	100	100	100
Duomeen L-7	beta diamine (7 C)	CAT B	100	52	2
Duomeen L-11	(11 C)	CAT B	–	–	100
Duomeen L-11 monoacetate		CAT B	100	100	100
Duomeen L-15	beta diamine (15 C)	CAT B	100	100	100
Duomeen L-15 mono oleate		CAT B	100	100	100
Duomeen L-15 dioleate[2]		CAT B	100	86	82
Atlas Chem. Ind.:					
G-2080			34	6	2
G-3300	alkyl aryl sulfonate	AN	100	96	92
G-3387			100	92	30
G-4500			98	26	0
G-4600			100	100	86
CA-630			66	18	2
Dow Corning Corp.:					
200 fluid			60	56	26
1107			60	52	24
General Aniline & Film Corp.:					
Igepal CO-530	nonylphenoxypoly (ethyleneoxy) ethanol	NI	70	70	68
Igepal CO-630	nonylphenoxypoly (ethyleneoxy) ethanol	NI	62	26	22
Igepon AP-78	oleic acid ester of sodium isothionate	AN B	20	0	0
Igepon T-77	sodium N-methyl-N-oleoyl taurate	AN B	72	50	36
Igepon TK-32	Sodium N-methyl-N-tall-oil-acid taurate	AN	12	0	0
General Mills, Inc.:					
Primary amines[2]:					
Alamine 4	lauryl amine	CAT	100	100	100
Alamine 6	palmityl amine	CAT	98	96	94
Alamine 7	stearyl amine	CAT	68	66	56
Alamine 11	oleyl amine		–	–	100
Alamine 15	oleyl-linoleyl amine	CAT	100	100	100
Alamine 21	coconut oil amine	CAT	100	100	100
Alamine 26	tallow amine	CAT	100	100	100
Alamine H-26	hydrogenated tallow amine	CAT	98	94	84
Seconary amines:					
Alamine 204[2]	dilauryl amine	CAT	100	74	10
Alamine 221[2]	dicoco amine	CAT	–	–	100
Tertiary amines:					
Alamine 304[2]	trilauryl amine	CAT	6	2	0
Alamine 336[2]	tricaprylyl amine	CAT	100	86	70
Aliquat 4	trimethyl lauryl ammonium chloride	CAT	16	0	0
Aliquat 21	coco trimethyl ammonium chloride	CAT	66	10	0
Aliquat 26	tallow trimethyl ammonium chloride	CAT	56	28	14
Aliquat 221	dicoco dimethyl ammonium chloride	CAT	–	–	100

Table 2 — Continued.

Supplier and material	Chemical description (R chain)	Type[1]	% mortality at conc. (ppm)		
			200	100	50
General Mills, Inc.: Tertiary amines:					
Aliquat H-226	di (hydrogenated tallow) dimethyl ammonium chloride		50	18	4
Aliquat 336	methyl tricaprylyl ammonium chloride		—	—	100
Aliquat 400	1:1 mixture Aliquats 26 and 221		94	98	92
Deriphat 170-C	N-lauryl β-aminopropionic acid	AMPH	100	98	22
Hodag Chem. Corp.:					
20-L	polyethylene glycol (200) monococonate	NI B	74	42	20
42-L	polyoxyethylene glycol (400) dicoconate	NI B	70	64	68
42-O	polyoxyethylene glycol (400) dioleate	NI B	42	8	10
E-11		NI B	34	24	14
DGL	diethylene glycol monococonate	NI B	88	68	32
GMO	glycerol monooleate	NI B	92	94	90
GMO-D	glycerol monooleate	AN B	90	82	78
GMR	glycerol monoricinoleate	NI B	94	56	14
GMR-D	glycerol monoricinoleate	NI B	64	28	14
E-4	a polyoxyethylene alkyl aryl ether	NI B	96	90	76
E-5	a polyoxyethylene alkyl aryl ether	NI B	40	14	0
E-10	a polyoxyethylene alkyl aryl ether	NI B	62	44	34
Nopco Chem. Co.:					
Agrimul 70-A	alkyl aryl polyether alcohol	NI	6	4	4
Gammanol	a sodium petroleum sulfonate	AN	40	38	18
Gammanol X	a sodium petroleum sulfonate	AN	48	12	6
Olin Mathieson Chem. Co.:					
Poly-tergent B-200	nonylphenoxy polyethoxyethanol	NI	82	74	56
Poly-tergent B-300	nonylphenoxy polyethoxyethanol	NI	84	74	64
Poly-tergent G-200	octylphenoxv polyethoxyethanol	NI	76	66	28
Poly-tergent G-300	octylphenoxy polyethoxyethanol	NI	44	52	12
Poly-tergent J-200	polyethoxyethyl aliphatic ether	NI	100	94	82
Poly-tergent J-300	polyethoxyethyl aliphatic ether	NI	98	98	8
Poly-tergent J-400	polyethoxyethyl aliphatic ether	NI	94	18	0
Poly-tergent J-500	polyethoxyethyl aliphatic ether	NI	40	10	0
Retzloff Chem. Co.:					
CX-40[3]	a polyoxyethyelene laurel ether		100	100	100
FR-47[3]	an alkyl benzyl quaternary		100	100	100
FR-56	an alkyl benzyl quaternary		84	24	0
FR-77	an amine salt of sulfonic acid		96	32	0
FR-79	an amine salt of sulfonic acid		90	6	0
NS-2	a poloxyethyelene phenolic resin		96	58	2
NS-29	an ethoxylated aliphatic alcohol		90	62	2
NS-30	an ethoxylated aliphatic alcohol		24	0	0
NS-139	polyoxyethyelene thioether		84	10	0
NS-176	a poloxyethyelene phenolic resin		16	2	0
NX-25[3]			100	100	100
NX-40			86	52	28
NX-60			100	74	54
NX-80	a nonylphenoxy poly (ethyleneoxy) ethanol		90	68	34
NX-100	a nonylphenoxy poly (ethyleneoxy) ethanol		88	40	26

Table 2 — Continued.

Supplier and material	Chemical description (R chain)	Type[1]	% mortality at conc. (ppm) 200	100	50
RAD-1110	a polyoxyethylated amine	AMPH	100	100	14
SPONTO 217	a blend of alkyl aryl polyether alcohols and special sulfonates	AN	100	92	22
Rohm & Haas Co.:					
Hyamine 3500	N-alkyl (C_{12},C_{14},C_{16}) dimethyl-benzyl ammonium chloride	CAT	100	66	20
Triton B-1956	modified phthalic glycerol alkyd resin	NI	28	16	12
Triton DN-65 (R-6837)			96	4	0
Triton GR-5 (R-6838)	dioctyl sodium sulfo-succinate	AN	78	42	0
Triton N-101	nonyl phenoxy polyethoxy ethanol	NI	58	40	18
Triton X-100 (R-6839)	isooctyl phenyl polyethoxy ethanol	NI	80	12	6
Triton X-114	isooctyl phenyl polyethoxy ethanol	NI	60	42	10
Stepan Chem. Co.:					
Toximul R	a sulfonate blend	NI	62	18	2
Toximul S	a sulfonate blend	NI	50	14	4
Witco Chem. Co., Inc.:					
Emcol AK 16-97-P	blend of alkyl aryl polyether alcohol and sulfonates	NI AN	32	10	2
Emcol AK-16-P	blend of alkyl aryl polyether alcohol and sulfonates	NI AN	86	58	12
Emcol H-140-B	blend of alkyl aryl polyether alcohol and sulfonates	NI AN	100	94	56
Emcol H-83-T	blend of alkyl aryl polyether alcohol and sulfonates	NI AN	100	62	10
AG-3-30	blend of alkyl aryl polyether alcohol and sulfonates	NI AN	32	0	0
H-141-B	blend of alkyl aryl polyether alcohol and sulfonates	NI AN	100	100	82

[1] For description of symbols, see footnote 1 in Table 1.
[2] Not readily soluble in acetone. In some of these precipitation occurred on standing and aging.
[3] LC_{50} and LC_{90} for 4th-stage larvae are: CX-40, 9 and 13 ppm; FR-47, 22 and 46 ppm; NX-25, 12 and 30 ppm respectively. Against pupae: CX-40, 5 and 13 ppm; FR-47 greater than 50 ppm; NX-25, 5 and 10 ppm respectively.

tivity at the levels tested. This group includes representatives from alcohols, amines, esters, N-substituted amino acid derivatives, ethers and other classes of compounds.

Lack of biological activity of these compounds does not detract from the surface activity of these compounds. The use of these materials in emulsifiable concentrates and other formulations is primarily based upon the hydrophilic and hydrophobic balances of the materials and possibly other physico-chemical properties of the compounds.

The second group of compounds contains chemicals which showed appreciable biological activity against mosquito larvae (Table 2). Here again a variety of compounds representing esters, ethers, alcohols, sulfonates, quaternary salts and fatty nitrogen derivatives were evaluated.

In the Armeen series of compounds, the activity increased as the carbon chain length increased. Armeen L-7 was less active than Armeen L-9, which in turn was less effective than Armeen L-11 and Armeen L-15. The acetate and oleate esters of Armeen L-15 showed similar activity in the ranges evaluated.

A similar relationship between structure and biological activity can be noted for the Duomeen series of compounds. Duomeen L-7 showed lower activity than Duomeen L-11. The relative activity of Duomeen L-11 and Duomeen L-15 within the range of concentrations tested was the same. The dioleate ester of Duomeen L-15 was less active than the monooleate

Table 3

Biological activity of organonitrogen compounds (*Onyx Chemicals*) against larvae and pupae of the mosquito *Culex p. quinquefasciatus*.

Material	Chemical description	Young (ppm)		4th (ppm)		Pupae (ppm)	
		LC_{50}	LC_{90}	LC_{50}	LC_{90}	LC_{50}	LC_{90}
Polysub 160	Polysubstituted nitrogen	3.7	10.0	20.0	44.0	36.0	>50.0
Polysub 161	Polysubstituted nitrogen	1.6	3.5	8.1	22.0	19.0	39.0
Polysub 164	Polysubstituted nitrogen	2.2	5.6	5.5	11.0	>50.0	–
Polysub 166	Polysubstituted nitrogen	1.4	3.1	4.2	7.8	1.8	3.0
Polysub 169	Sulfanilic acid der.of alkyl isoquinolinium bromide	6.0	20.0	12.0	35.0	19.0	40.0
Polysub 170	Polysubstituted nitrogen	4.4	11.5	17.0	38.0	14.0	37.0
Polysub 173	Polysubstituted nitrogen	2.8	9.5	>50.0	–	>50.0	–
Onyxide 172	Ethylbenzyl dimethyl alkyl ammonium cyclohexylsulfonate	1.5	2.7	>50.0	–	>50.0	–
Onyxide 3300	Alkyl dimethyl benzyl ammonium saccharinate	2.8	9.5	35.0	50.0	29.0	54.0
Ammonyx CO	Cetyl dimethyl amine oxide	29.0	72.0	>50.0	–	14.0	37.0
Ammonyx LO	Laurel dimethyl amine oxide	>50.0	–	>50.0	–	>50.0	–
Ammonyx MCO	Myristyl-cetyl dimethyl amine oxide	29.0	48.0	>50.0	–	25.0	50.0
Ammonyx MO	Myristyl dimethyl amine oxide	23.0	43.0	>50.0	–	25.0	50.0

Table 4

Biological activity of various Tergitol (Union Carbide) nonionic surfactants against 4th-stage larvae and pupae of the mosquito *Culex p. quinquefasciatus*.

Material	Chemical description	24-hr. % mortality[a] Larvae (ppm)		Pupae (ppm)	
		10	50	10	50
Tergitol 12-P-6	Dodecyl phenyl polyethylene glycol ether	43	73	100	100
Tergitol 12-P-9[b,c]	Dodecyl phenyl polyethylene glycol ether	45	88	95	100
Tergitol 12-P-12	Dodecyl phenyl polyethylene glycol ether	0	8	90	100
Tergitol 12-M-10	Dodecyl mercapto polyethylene glycol ether	0	0	8	41
Tergitol TMN	Trimethyl nonyl polyethylene glycol ether	0	0	3	43
Tergitol NP-14[b,c]	Nonyl phenyl polyethylene glycol ether	13	93	80	100
Tergitol NP-15	Nonyl phenyl polyethylene glycol ether	0	53	98	100
Tergitol NP-16[b,c]	Nonyl phenyl polyethylene glycol ether	13	75	83	100
Tergitol NP-27[b]	Nonyl phenyl polyethylene glycol ether	0	18	53	100
Tergitol NP-33[b]	Nonyl phenyl polyethylene glycol ether	8	18	8	65
Tergitol NP-35	Nonyl phenyl polyethylene glycol ether	0	0	0	55
Tergitol NP-40	Nonyl phenyl polyethylene glycol ether	0	0	0	18
Tergitol NP-44	Nonyl phenyl polyethylene glycol ether	0	0	0	13
Tergitol NPX		10	58	5	93
Tergitol OP-15		0	5	0	48
Tergitol 3-A-6	Tridecyl polyethylene glycol ether	0	63	83	100
Tergitol 15-S-12[b]	Polyethylene glycol ether of linear sec. alcohol	0	20	10	68
Tergitol TP-9[b]		0	3	58	100
Tergitol XD	Polyalkylene glycol ether	0	0	0	3
Tergitol XH[b,c]	Polyalkylene glycol ether	8	8	3	0

[a] Mortality pertains to the treated stage only.
[b] Some adults emerging died on the surface
[c] Some treated larvae pupated, but died in the pupal stage.

ester. Certain relationships between structure and biological activity were also noted for the Alamine and Aliquot series of compounds.

A group of polysubstituted organic nitrogen compounds were evaluated against young and 4th-stage larvae and pupae (Table 3). The younger larvae were more susceptible to these compounds than the 4th-stage larvae. In general, these compounds showed a low level of activity against the larvae and pupae. Two compounds, Polysub 166 and 169 were quite active against the larvae and pupae. The former compound was more effective against the pupae while the latter was effective against the larvae.

Table 4 presents information on the activity of alkyl polysubstituted glycol ethers. These are nonionic surfactants which find many uses in household and industrial detergents. None of these compounds are considered to have appreciable activity against the larvae. However, against the pupae, Tergitol 12-P-6, 12-P-9, 12-P-12 and NP-15 manifested a moderate level of activity at the concentration of 10 ppm. It is possible that further search in the glycol ethers might produce more promising compounds.

The fatty nitrogen derivatives as a group are very promising (Mulla, 1967). These materials affected the larvae in the same manner as biologically active petroleum oils. The larvae were affected within a few minutes. Mortality, unlike in the case of organophosphate insecticides, occurred within a few hours (1-4) after treatment. Typical symptoms of intoxication were initiated by hyper-excitation and curling up of the larvae. The affected larvae frequently curl up and bite on the siphon tube. Within an hour or so the affected larvae sink to the bottom and are unable to surface readily. The larvae may wriggle on the bottom when disturbed but eventually die.

Limited field and laboratory studies on the biological efficacy of these compounds has been accomplished. These studies are reported elsewhere (Mulla 1967). These compounds offer good possibilities for mosquito control in the future.

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SUBMITTED PAPERS SESSION

CONCURRENT

WEDNESDAY, FEBRUARY 8, 8:30 A.M.

WILLIAM C. REEVES, *Presiding*

THIOKOL SWAMP SPRYTE EQUIPPED WITH AUTOMATIC COMPRESSED AIR SPRAYING UNITS FOR APPLYING GRANULE AND LIQUID INSECTICIDES

JACK H. KIMBALL AND ALBERT H. THOMPSON
Orange County Mosquito Abatement District
Santa Ana, Calif.

The use of an amphibious track vehicle, called a "Weasel", and similar to the Thiokol Swamp Spryte vehicle, is not new to the Orange County Mosquito Abatement District.

When the District was formed in 1947, a complete survey was made of large breeding sources consisting of some 6,000 acres of salt marsh, 1,025 acres of private duck club ponds, dairy pastures and other sources. At that time, it was decided an amphibious track vehicle was needed. Our first Weasel (Army surplus cargo carrier) was purchased through a war surplus dealer. Since then, we have purchased four more from other sources, using some for spare parts. Our last Weasel recently became inoperable because the tracks had worn beyond repair and the hull and bulkhead had rusted out.

At the present time, however, some 2,500 acres of the salt marsh remains in its natural state and is subject to fresh water flooding from rainfall and storm water run-off, as well as tidal water flooding. Also, there are approximately 300 acres of private duck club ponds under surveillance. It is the property owners' responsibility to prevent unnecessary mosquito breeding; but in cases of emergency, breeding sources will be treated by the District to protect the residents of the surrounding community from mosquito annoyance. In addition, there are rainwater depressions, flood channels and other sources that cannot be adequately treated unless the right equipment is used.

At present our population is over 1,100,000, with subdivisions being built adjacent to or close to large mosquito sources. These sources cannot be adequately controlled with standard equipment so the District purchased a Thiokol Swamp Spryte, Amphibious Model 1301, and a Trailmaster tilt-type trailer for transporting the Spryte.

For the most effective control of mosquitoes and chironomidae gnats, the following equipment was installed for dispensing both liquid and granule insecticides:

1. A mounting plate was built and installed above the clutch housing. A Bendix-Westinghouse Tu-Flo 500 water-cooled compressor was mounted on this plate. This compressor is driven by belt pulley, with the drive pulley installed on the front universal joint flange. This compressor runs continuously while the engine is running; but actual compression of air is controlled by a governor, which stops or starts the compression of air by loading or unloading the compressor in conjunction with its unloading mechanism. This is done when the air pressure in the system reaches the desired maximum or minimum pressures. The start recovery pressure differential is 15-20 PSI.
2. After the installation of the compressor, we mounted a 90-gallon horizontal hydro galvanized compressed air spray tank. This tank will be used for oil insecticide and is equipped with a ½" Wabco Air Regulator, pressure range 0-150 PSI, number P55119-1 and a ½" Wabco R-2 line filter, number P7104. This filter assures dry compressed air for the granule gun. The tank also acts as an air reservoir for operating the Orange County compressed air granule gun.
3. The granule gun is a Kelco Model G790C sandblast gun equipped with 1/16" and 3/32" air jets in combination with 3/16", 1/4" and 5/32" tungsten carbide nozzles. This has proved to be a reliable and trouble-free metering device for granules of many types and sizes.
4. A plastic diaper bucket, holding approximately 55 lbs. of granules, permits the operator to spray from the moving vehicle. In order to draw the granules from the bucket, a 16-gauge galvanized metal lid is made to fit tight on the bucket by crimping the edges. Then a round hole is cut in the center of the lid so that a ½"x3" pipe can be soldered into the hole. A piece of ¼"x21" pipe, bent at one end to a 90° angle, is then inserted into the 3" pipe approximately ¾" from the bottom of the bucket. Then a suction hose is attached from this pipe to the granule gun.
5. A Homelite Mist Blower, Model 24B4 (no longer manufactured) was mounted on the top center of Spryte rear deck. This blower is designed to apply liquid insecticides such as water emulsions, oil base or concentrate. The liquid is fed through a pressure relief valve into the air stream by the compressed air tank and is atomized and distributed by the 150-mile-per-hour blast from the blower. Horizontal coverage is approximately 50 - 200 feet depending on the wind.

In modifying this blower, a 12-volt Ford tailgate window lift motor and transmission assembly was installed to rotate the blower housing 180° to the right and left by using a chain drive. To operate the motor, a Ford tailgate window lift switch (spring loaded to off position) was installed.

The rope starter was eliminated by installing an electric starter. A starter ring gear was installed on the fly wheel by a local machine shop. Then a used 6-volt electric starter assembly (industrial) Model #MAK-4008, Auto-light was purchased. To install the starter, a mounting plate was bolted to the mist blower frame enabling the starter to line up with the ring gear on the fly wheel. A starter solenoid and starter button switch were used to actuate the starter.

To control the liquid insecticide to the air stream, a 12-volt ⅛" electric solenoid valve was installed, operated by an on-off switch.

A control panel was installed in reach of both the driver and the operator enabling either one to operate the mist blower by remote control, thus preventing accidents caused by crawling back and forth over the tank. Although the District uses a two-man crew to operate this vehicle, it was designed for a one-man operation if necessary.

INTERRUPTION OF DIAPAUSE AND REARING LARVAE OF *CULISETA MELANURA*

Richard O. Hayes and Herbert K. Maxfield
Communicable Disease Center, U.S.P.H.S.
Disease Ecology Section, Greeley, Colo.

Abstract

Development was reinitiated among larvae of *Culiseta melanura* in winter diapause by simultaneously increasing the photoperiod to 20 hours and providing a liver-yeast nutrient. The laboratory technique was used successfully for two years for the routine production of adult *C. melanura* during winter months in Massachusetts. Several dietary regimens were tested for rearing larvae from individual *C. melanura* egg rafts hatched in the laboratory. Ninety-two to 95 percent pupation occurred using diets of 0.12 g. three days per week, 0.12 g. five days per week, and 0.24 g. five days per week.

A LIGHT WEIGHT ENTOMOLOGICAL SURVEY KIT

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Insect Control and Research Inc., Baltimore, Maryland
and
Clyde S. Barnhart
Limited War Laboratory, Aberdeen Prooving Ground, Maryland

ABSTRACT

A light weight kit to be used in conducting short surveys of medically important arthropods for epidemiological purposes has been developed. The kit weighs approximately 1½ pounds and includes a carrying case, notebook and data cards, aquatic/aerial net, plastic bowl, plastic eyedroppers, aspirator and cartridges, suction device, magnifier, scissors, ruler, alcohol container, plastic bags, tape, killing tube, plastic vials, brush, comb, forceps, cotton balls, flannel cloth, mailer and instruction sheets.

REPORT ON AGRICULTURAL WASTE WATER SYMPOSIUM

George R. Whitten
Delta Mosquito Abatement District, Visalia, Calif.

On April 6-8th, 1966, a symposium devoted exclusively to agricultural waste waters was held on the campus of the University of California at Davis. Seven people from mosquito abatement districts in the state and one member of the Bureau of Vector Control were in attendance. This symposium was the first of several planned and sponsored by the Central Valley Regional Water Quality Control Board.

I would like to quote briefly from report number ten of the proceedings of the symposium.The objectives of this symposium are to:

1. alert all concerned parties to the need for management of agricultural wastes with respect to optimizing the quality and usefulness of state waters and bring to bear upon the problem the knowledge and background of all concerned with this important matter;

2. identify areas of inadequate knowledge or of inadequate control mechanisms so that appropriate studies and efforts may be initiated towards evolving competent agricultural waste management systems; and,

3. gather into one publication all pertinent data related to management of water quality as affected by farm wastes.

The problems, both general and specific, were discussed very thoroughly to the extent of existing knowledge. The areas where lack of knowledge was apparent were outlined and hopefully will be rectified in the near future. At the present time four main headings are being used to define waste water, dissolved minerals, siltation, nutrients and pesticides.

The impact of these waters on various areas of use such as domestic, municipal, industrial, recreation, wildlife and agricultural, was discussed in some detail. Each of these users of water has a standard which he dare not exceed for any extended period or trouble will result.

Disposal of agricultural waste waters by various methods such as percolation, natural and artificial drains, removal from the area, and by reclamation and treatment, received considerable attention. There is a growing awareness of the importance of maintaining water in a usable state. Once contaminants are introduced it is necessary to dispose of this water which is not only a waste but also very costly.

The management problems with respect to the legal aspects seem to be very closely tied to the interpretation of what is considered reasonable use or beneficial use of water. There was also the question "Is there a right to pollute water?" Another question which was discussed is "What is pollution?"

The economic consideration requires identification. There are many variables, and water being a limited resource must ultimately be fully developed, so that the economics of handling waste water is determined by time, or to state the case another way, the timing is determined by economics. Technological solutions must be legally sound and economically feasible before they truly solve any problems.

The position of regulatory agencies is becoming more prominent each year. The federal role is definitely expanding legislatively, financially in terms of funds and grants, and technically in terms of assistance, research, and collection and dissemination of information.

Until very recently the state has been preoccupied with industrial waste water problems. However, in 1956 agricultural irrigation and drainage water was defined as industrial waste and subject to state regulations. It is estimated that 20% of the pesticides used in the United States are used in California. The California Department of Agriculture keeps very close watch on the use of these pesticides and controls their role as a contaminant or pollutant of our agricultural waters.

We also have a State Water Quality Control Board which sets policy and exercises budgetary control over regional boards. These boards control discharge of any waste into a water course.

Representatives from Water Quality Control Agencies, the California Farm Bureau Federation, The California Legislature and The Irrigation Districts Association were brought together in a panel which acknowledged the problem and the importance of instigating some action. They discussed their organization's outlook and indicated the desire to find solutions which will be equitable to all involved.

Agricultural waste water problems must be minimized. State-wide water quality objectives will be established. This is the thinking of the people investigating and studying this problem at this time.

I feel that mosquito abatement districts have a very real interest in solutions to these water quality problems and the methods that are used to accomplish them. Waste water has been, and will continue to be, our greatest mosquito breeding source for many years to come. The solutions that might satisfy agriculture conceivably either increase our problems or only partially solve them.

The California Mosquito Control Association, representing mosquito control in California, has a responsibility to share with agriculture in finding equitable solutions to these mutual problems.

A COLLAPSIBLE PORTABLE VEHICLE MOUNTED INSECT TRAP

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First U.S. Army Medical Laboratory No. 1
Fort George G. Meade, Maryland

ABSTRACT

Extensive aerial spray operations in the First U.S. Army area created a need for a simple means of evaluating mosquito populations in assessing the extent of control achieved with aerial spray. The vehicle trap was selected as a most promising piece of equipment for this requirement. A lightweight portable trap was designed and constructed. This prototype functioned very well and was used throughout the summer season for aerial spray evaluation and as a general sampling device.

The final design for military testing is described as follows:

The hoop or mouth of the trap is ¾ inch aluminum tubing 5 feet wide by 2 feet high. This hoop breaks in the center of the horizontal axis with slide joint at the top and bottom. This folded hoop sets the maximum dimension of the collapsed trap at 2½ feet by 2 feet. Guy ropes are used to secure the top of the hoop. A tapered net constructed of fabric and nylon netting is sewn to the hoop and has a fiber glass cone inserted at the rear of the net for tensioning and support. At the extreme rear of the net a band of fabric is sewn in for strength around the cone. The fiber glass cone has a maximum diameter of 4 inches. The minimum diameter is extended as a tube projecting from the rear of the cone. One-quarter inch nylon ropes are sewn into each corner of the net. These ropes are attached to the hoop and secured by grommets on the cone. An adjustable yoke is fitted around the cone extension and attached to the rear mounts. A CDC trap collecting bag is used for collections.

THE "CDC SWEEPER", A SIX VOLT MECHANICAL ASPIRATOR FOR COLLECTING ADULT MOSQUITOES

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Disease Ecology Section, Greeley, Colo.

ABSTRACT

A six-volt battery powered mechanical aspirator, called the "CDC Sweeper", is described. Mosquito collections were obtained with this collecting unit in Hawaii, Texas, and Colorado during 1966, and its performance indicated its usefulness for collecting adult mosquitoes from shelters and other resting habitats. Some of the advantages of the CDC Sweeper are its relatively low cost, its economical operating expense, its direct collecting action that eliminates the need to transfer specimens, its collection of undamaged specimens, its quiet operation, its ease of operation, and the speed with which it collects large numbers of resting or flying mosquitoes.

STATISTICAL APPLICATIONS TO REPELLENCY ASSAY

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IIT Research Institute
Life Sciences Research, Chicago, Ill.

ABSTRACT

An assay system was devised which permits an economical screening of potential mosquito repellents. The assay system utilizes a method whereby mosquito biting is electronically detected. An index of mosquito repellency, which is the sum of percent of mosquitoes engorged plus percent of biting time (as determined electronically) during a 30-min. exposure period was derived by using discriminant function analysis. These

multiple measurements for tests using minimally treated host mice and untreated controls were used to derive a function to give best separation between the two groups. Hence a simple index consisting of the sum of these two variables is proposed as an indicator of repellency. Analysis of variance was performed on this index and the confidence interval for significant variations from the control group is given as a function of the number of independent trials. Day-to-day variations in mosquito biting were found to be statistically significant, but the number of mosquitoes exposed and the age of the mosquitoes at the time of exposure did not prove to be significant in our assay system. Contrast of control and test data on a day-to-day basis has been incorporated into a computer program.

A PRELIMINARY REPORT ON A POTENTIAL NEW MOSQUITO CONTROL WEAPON

GLENN M. STOKES
Department of Mosquito Control
Jefferson Parish, Metairie, La.

The potential new weapon of which I will speak this morning illustrates parallel evolution in methodology in two different countries. The United States' solution to laying down a smokescreen for the protection of naval vessels was to heat diesel fuel to a high temperature.

The Argentinia Navy's answer to the production of a smokescreen was to combine $SiCl_4$ and ammonia water. This forms a very dense and heavy fog.

Parallel evolution has now proceeded one step further. Certain United States technologists introduced insecticides into the diesel, using it as a vehicle to carry insecticide. Whereas, certain Argentinian technologists introduced insecticides into $SiCl_4$ (which is an excellent solvent in the same class as CCl_4) and used the end products of a chemical reaction between $SiCl_4$ and ammonia water—hydrated Silicon dioxide and NH_3 Cl, as carriers of an insecticide.

In 1965, this Argentinian method of fogging was patented in Argentina and patents were filed for in 15 other foreign countries, including the United States. Patents have now been granted in Brazil and Italy. Following efficacy tests in Argentina against more than 20 species of insects and following registration with the appropriate Argentinian agencies, the fog was used to combat flies in the city of Buenos Aires on a 300-acre garbage dump. This fly problem has been successfully abated for two years now with this fog, using malathion as the active ingredient.

Seven months ago this method was introduced into the United States, preliminary tests have been made, and an application has been submitted for a label.

These preliminary tests have been promising. However, more rigorous and extensive testing must be conducted before conclusions can be reached and before a label is granted.

Application equipment and chemicals have been offered to the U.S.D.A., U.S.P.H.S., several state boards of health, and to several state experiment stations for thorough and complete testing of the efficacy, safety and efficiency of this new method.

The assets of this potential new weapon are that it is: (1) very dense, (2) has good penetrating properties, (3) has apparent long residual, (4) has apparent increased swath width, (5) a reduced dosage rate of active ingredients is required, (6) no heat is required, and (7) the low cost of carrying out an effective mosquito control program (approximately one-fifth the cost of operating conventional thermal fogging equipment). Accordingly, this would bring mosquito control within the reach of virtually any agency or group that desires it.

ENCEPHALITIS SURVEILLANCE IN HARRIS COUNTY, TEXAS

ROBERT E. BARTNETT, SAM RICHE AND RICHARD P. JONES
Harris County Mosquito Control District
Houston, Texas

The Harris County Mosquito Control District was voted into existence in 1964 following an epidemic of St. Louis encephalitis. Harris County, consisting of 1,75 squ4are miles, has a population estimated at 1.6 million people with the majority of these residing in the principal city, Houston.

The primary concern of the Mosquito Control District has been the surveillance of the encephalitides and the control of potential vector mosquitoes.

In the District office laboratory work is performed by District biologists and technicians in order to determine what species of mosquitoes exist in the county, and the extent of their relative densities. There is not one good method to determine densities, therefore, a number of methods are used. These include: New Jersey type light traps, CDC battery powered traps, bait traps, resting station counts, larval collections, and landing rate counts.

Of 64,498 adult mosquitoes caught in New Jersey light traps, 52.4% were *Psorophora confinnis*, 10.5% were *Culex salinarius*, 7.9% were *Culiseta inornata*, 3.5% were *Anopheles crucians*, and 0.8% were *Culex quinquefasciatus*. In addition, 16.3% were males and 8.6% were distributed among other species. These collections were accomplished by operating 20 traps a total of 1,255 trap nights.

Of 7,605 larval collections made by inspectors, 30% were *Culex quinquefasciatus*, 25% *Psorophora confinnis*, 12% *Culex salinarius*, 9% *Culiseta inornata*, and 24% distributed among other species.

In order to determine principal pests, inspectors use aspirators to collect adult mosquitoes landing on them and in resting locations during the course of their inspections. The adults in 1,158 collections were composed of 28% *Psorophora confinnis*, 12% *Culex salinarius*, 11% *Aedes sollicitans*, 10% *Culiseta inornata*, 7% *Culex quinquefasciatus*, and 33% other species.

From these figures it can be seen that the Harris County vector of St. Louis encephalitis, *Culex quinquefasciatus*, is the principal mosquito taken in larval collections but is seldom collected by other methods. No doubt the limitations of collecting sites along road-sides creates some of the differences, but this information does show that *Culex quinquefasciatus* mosquitoes do occur in sufficient numbers to be a potential vector problem throughout the county.

As further data is collected and added to that already recorded, and as a detailed analysis continues, the patterns of Harris County mosquitoes will become more precisely known and predictable. One cause for concern, *Culex tarsalis*, carrier of western encephalitis, appears in sufficient numbers in spring and late fall to present a potential threat to horses and humans. Information gathered by District personnel on this mosquito will, no doubt, yield better surveillance techniques and control measures in the future.

The overall mosquito picture during the year was one of generally constant production with one extremely heavy period in May. The average collection was 51 mosquitoes per trap night. This was a little lower than for the fall of 1965, yet indicative of a fair level of annoyance at most times. To date, 34 species of a possible 50 reported from Harris County have been found to be responsible for these results.

A total of 28,409 mosquitoes were collected and processed for virus isolation attempts. Since collections of this type are made by utilizing battery-powered aspirators in resting sites such as horse barns and chicken houses, the mosquito *Culex quinquefasciatus* proved to be the most abundant. Collections were also made with aspirators while taking landing rate counts. Mosquito numbers changed in the proportions caught when the collection methods varied. *Psorophora confinnis* was the principal mosquito taken by this method. Seventy-five percent of the total number of mosquitoes was *Culex quinquefasciatus.* Some mosquitoes, such as those in the *Uranotaenia* spp., were not obtained in significant numbers in live collection, although at times they did appear in New Jersey light trap collections on a fairly large scale. In January and February of 1966, very few collections were made. As a result, *Culiseta inornata,* a predominant winter species in this area, was not caught abundantly.

By March of 1966, the virus laboratory, which is a cooperative effort of the Texas State Department of Health, County Health Department, Mosquito Control District, and the City of Houston Health Department, was ready to commence surveillance studies. The methods utilized followed the criteria set forth in the Communicable Disease Center booklet, "Methods for Collection and Processing Mosquitoes for Arbovirus Isolation," and in the third edition of "Diagnostic Procedures for Viral and Rickettsial Diseases," published by the American Public Health Association, Incorporated.

Nine virus isolations were made in 1966. Seven of these were identified by the Texas State Department of Health Laboratory as Hart Park virus. All of these pools were comprised of 43 to 60 *Culex quinquefasciatus* females. The first isolation occurred in a mosquito collection of May 26, and the last in a mosquito collection caught on August 15. A mixed pool of *Aedes atlanticus-tormentor* and *Aedes infirmatus* mosquitoes, which was collected on July 15 and July 20, produced a virus isolation. This virus was identified by the Texas State Department of Health as California encephalitis, probably of the San Angelo strain. On June 10, 33 *Psorophora ferox* mosquitoes yielded an isolate of *Bunyamwera* virus. This virus was identified by the Communicable Disease Center as being probably of the Tensaw strain. The laboratory is attempting to develop antigen and immune serum for local testing of these two viruses.

Another important area of surveillance concerned avian hosts. Since most workers consider that it is necessary to have an epizootic before conditions will permit a spill-over into the human population, a major portion of our work is aimed at determining the activity of SLE, WE, and EE in bird populations. A program of field surveillance was started providing an information base line that makes Harris County Mosquito Control District have one of the most intensive programs in the country. The rapid availability of laboratory results on the blood samples taken from trapped wild birds provides for a unique coordination of mosquito control operations and information on viral activity.

The trapping activity was concentrated in nine permanent trapping sites with approximately 20 other stations sampled at random. There were three considerations involved in choosing a trapping site. First, and of primary importance, was the relative proximity to residential areas where numbers of SLE cases were high in 1964. The second consideration involved evidence of an existing bird population in numbers large enough to produce feasible catches. It was observed that railyard centers harbored great flocks of house sparrows and domestic pigeons due to spillage of grain and other food products. The third consideration centered around the availability of the site and whether or not our equipment could be used at this site.

With criteria set, two days a week a two-man crew using one to four Japanese No. 4 mist nets sets up at four sites. The birds are removed as soon as possible from the nets, at which time 2/10ths of a cc. of blood is removed from the jugular vein. The bird is then banded and released. The blood is placed in glass vials containing 8/10ths cc. dilutent. Rubber stoppers are used and proper labels are attached prior to being taken to the laboratory for virus studies.

Mist nets, cannon nets, box traps, and drive traps were all employed at various times accounting for a total of 2,757 blood samples from 91 bird species. These were studied in the City-County Virology Laboratory for SLE, WE, and EE virus antibodies. Of the total bloods which were processed through the laboratory, there were 39 positive SLE HI titres and five western encephalitis HI titres recorded. All specimens found with positive titres were retested to confirm results. Thus far we have a 1.1 percent positive level. A sharp rise would probably indicate increased virus activity. We feel that a level up to 10% positive in young birds would indicate an epizootic which would be critical from the standpoint of spill-over into the human population.

Federal and state wild bird collection permits were required in order to set up the trapping program, and federal leg bands were used for future identification. Of the total 2,575 birds trapped, 1,425 were banded and activity reports sent to each governmental agency.

Birds which were not caught in abundance and those uncommon species that died from the trapping or bleeding were taken to the Texas A&M University Wildlife Department as study specimens.

In addition to the foregoing information, a three-day trip was made to Dallas during the epidemic there in order that Harris County techniques could be confirmed. Of 164 birds trapped, 28 were HI positive for SLE or a total of 17.07% showing a positive titre. Of great importance was the collection from one flock in one specific location. Of 109 house sparrows collected, 26 were HI positive for a startling 23.85% level. This may very very significant since it would indicate that one trapping area could be higher than another within a community. By finding the infected population of birds, more effective mosquito control measures could be concentrated in their roosting sites to break the transmission chain.

The District maintains six Greely sentinel chicken sheds in Harris County. The birds are changed three times per year in order that young birds might be in these locations at all times. Baby chicks are obtained from the Texas A&M University, bled to test for the presence of antibodies for WE or SLE, and held for two weeks in the sentinel shed with the older chickens. The older chickens are studied for development of antibodies during this holding period before their disposal.

According to reports received from the virus laboratory, conversions to western encephalitis were found in the chickens in three sheds. They were located at the prison farm in the southeast side of the county, at Sheldon reservoir in the northeast part of the county, and in Cypress in the northwest section of the county. These areas can be described as rural situations rather than urban. The sheds that were in the urban area did not show conversions. One horse from the northwest part of the city of Houston had a fourfold HI titre rise for western encephalitis from 1:82 and 1:320. One human case of St. Louis encephalitis was confirmed in a boy who had been in Corpus Christi, Texas, up to 12 days before the onset of the illness. Physicians are being contacted with the aid of the Harris County Health Department to encourage them to utilize these laboratory facilities.

Mr. Reuben D. Wende, Laboratory Director, has reported that additional services are available to physicians through the use of tissue culture techniques. This will aid our surveillance program through the identification of nonarboviruses which cause similar human symptoms. With this information available, better coordination of mosquito control activities can be obtained.

A LOW COST AIRBOAT FOR USE IN MOSQUITO CONTROL

Albert H. Thompson

Orange County Mosquito Abatement District

Santa Ana, Calif.

The Orange County Mosquito Abatement District, consisting of 777 square miles, has approximately 450 square miles of this area under surveillance and treatment. In this area there are abandoned sand and gravel pits used for holding waste water. These pits cover approximately 5 to 10 acres each, and are from 40 to 50 feet deep. The location of these pits eliminates the possibility of larviciding by hand or power equipment.

In addition to the above sources, there are natural depressions, earthen dams and other low areas that are filled with rainwater during the winter months. With normal rainfall, about 16 inches per year, these sources hold water well into the summer months. We have 131 such rain-filled depressions with a total area of 186 acres. Many of these depressions are too deep to walk, and inaccessible to conventional equipment.

The District has a six-foot dinghy which is used for making inspections but is inadequate for larviciding due to its small size and capacity. The use of airboats in mosquito control is not new; however, after seeing "Brian's Breezy Bathtub," described more formally in boat for Use in Mosquito Control" (Mosquito News, June 1965), it was felt that such a boat could be adapted to Orange County's problems.

Controlled Airstreams, Inc., Gardena, California, was contacted for information on portable air-thrust units. This company constructs air-thrust units primarily for fire fighting (foam), smoke removal and controlled burning. Their larger machines are used to create hurricanes, wind or sand storms for the movie industry. In addition to the above units, this Company markets the McBride Air-Thrust Portable Power Unit for small boat propulsion. The 24" unit (priced at $240.00) is the one used by Orange County Mosquito Abatement District at present. The advantages of an air-thrust unit over traditional propelling methods are:

1. Economy that can't be beat because the engine is capable of operating 45 minutes at full throttle on only 1½ quarts of fuel. Therefore, if you should, for instance, average eight miles per hour, you would travel six miles on 1½ quarts of fuel.
2. Increased maneuverability to the extent that you can spin a perfect 360 degree circle, shift into reverse by rotating the Unit 180 degrees which lets the harmless airstream expend its energy over the bow without any discomfort to you or passengers.
3. Elimination of shoring problems, shearing of pins, fouling of water pumps. In fact, you have NO prop worries since there is nothing below the surface of the water.
4. Lower speeds without lugging or motor failure and if your craft draws five inches of water you can travel through water only six inches deep.
5. Instant ignition without pulling on starter ropes - no extras to buy - no batteries to run down - no more expensive repair bills.

The McBride Air-Thrust generates a tightly confined airstream that thrusts you over the water's surface. Airboats in the Everglades have long used the same general principle. Not until Controlled Airstreams, Inc. perfected a portable unit with unique duct design, did air-thrust propulsion become ideal for use by anyone on small craft of all types. A powerful, densely compacted stream of air pushing against the atmosphere provides your motive power. Speeds that might be obtained depend on the size, gross weight of your boat, passengers and hull design. The 18 inch unit is capable of pushing a 12 foot canoe five miles per hour into a ten mile per hourwind. The 24 inch unit, which we use in Orange County, propels the same craft at about nine miles per hour. Gross weight is about 500 pounds. Both units are powered by a 2½ horsepower engine. It might be well to remind ourselves that many lakes and waterways have a maximum speed of five miles per hour. The 36″ is powered by a 10 hp engine and develops 72 lbs. of thrust. The 18″ generates 16 lbs. while the 25″ develops 22 lbs. (2½ hp not for fast rivers or ocean currents).

The engine is made special for use by Controlled Airstreams, Inc. by the Clinton Corp. Parts are readily available anywhere in the world from Clinton's vast network of factory distributors. In fact, there is nothing else to wear out or repair on the McBride Air-Thrust except small inexpensive engine parts. The engine is equipped with a 250 lb. torque ratchet type impulse starter to assure instant ignition and baffled muffler, switch, waterproof ignition, roller bearings next to P.T.O., fuel tank and fuel level gauge. Type of fuel is outboard mix. The two-bladed props are water and warp proof and will stand salt water exposure. Duct is of fibre glass; struts, safety grills, and tubing are chrome plated. Transom clamp is of aluminum and will fit transoms through 20 degree pitch and 2 inches thick. It stows neatly into the trunk of an automobile. The ″ weighs 42 pounds, 24″ weighs 49 pounds, including clamp.

The boat used by the District operates well with the air-thrust unit. This boat, purchased from Montgomery Ward, is a 12 foot aluminum Pram (flat bottom, 44 inches wide and 14 inches deep), weighs 85 pounds and costs $99.00. It is very versatile, will maneuver in 6″-8″ water depth with 700 lb. load. It is easy to carry and fits on the top of a car or in the back of a station wagon. Montgomery Ward has now added a 14-foot aluminum Pram at $125.00 and a 16-foot Pram at $169.00 to its boat department. The Airboat is very maneuverable and requires very little time to learn to operate.

Granules and oil are used in larviciding. Granules are applied by a portable air compressor unit, using the Orange County Compressed Air Granule Gun, horn seeder or Whirlybird seeder. A 3 gallon spray can, with the portable air compressor to keep up pressure, is used to apply the oil.

INSECTICIDAL AND NATURALISTIC CONTROL OF CHIRONOMID LARVAE IN LAKE DALWIGK, VALLEJO, CALIFORNIA

Embree G. Mezger
Solano County Mosquito Abatement District, Suisun, Calif.

There are several accounts concerned with problems arising from the mass emergence of chironomid midges in California (Grant, 1960; McFarland, 1960; Grodhaus, 1963, Bay, Anderson and Sugerman, 1965; and others).

Residents near Lake Dalwigk, in Vallejo, Solano County have registered numerous complaints of mosquito-like insects, phich proved to be chironomid midges. These midges were observed to migrate to lighted windows at night, stain bedding on outdoor clothes lines, obscure motorists' vision, and attract large numbers of spiders.

Lake Dalwigk was constructed in 1956 on a reclaimed salt marsh by the Vallejo Sanitation and Flood Control District. It serves as a flood-water holding basin and prevents inundation of surrounding properties during the rainy season. If the basin holding capacity is reached, excess water may be pumped into Mare Island Strait which is located approximately one-half mile to the west.

The lake was formed by excavation and has a surface area of approximately 31 acres. It has three inlets and an outlet (Fig. 1). The average water depth is 2.5 ft. with an annual temperature range of approximately 35° to 74° F. Water salinity may fluctuate considerably depending upon the amount of runoff. Salinity is usually low in winter, spring, and early summer, becoming progressively higher as runoff lessens and evaporation increases with the elevated air temperatures in mid-summer. Pumping of water into the basin from Mare Island Strait is often necessary during the summer to maintain the aesthetic appearance of the lake. This, too, contributes to the summer increase in salt content since the strait, formed by the confluence of the Napa River and San Francisco Bay, may be quite saline at this time of the year.

The substrate is predominantly a thick black "ooze" with lesser regions of hard soil.

The lake undergoes periodic algal blooms. Extensive growths of grass wrack, *Zannichellia palustris* L., occur seasonally offshore, and there are scattered stands of cattail, *Typha latifolia* L., at the edge. The area around the lake is dominated by annual grasses.

The open water surface is frequented by gulls, ducks, and coots. The killdeer is a common shoreline visitor as is the muskrat. The lake has a moderate fish

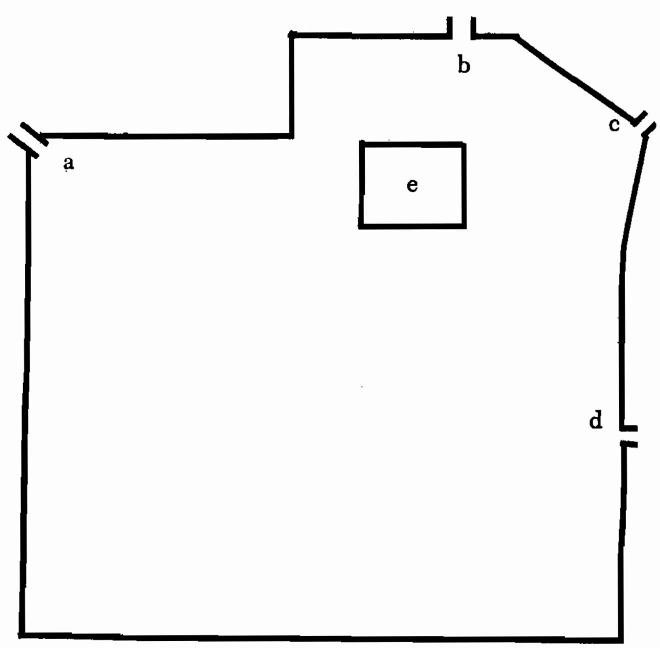

Figure 1 – Diagram of Lake Dalwigk, Vallejo, California, showing the outlet (a), the inlets (b,c,d), and the carp-holding 1/10 acre fence enclosure (e).

population which includes the mosquito fish, *Gambusia affinis* (Baird and Girard); the threespine stickleback, *Gasterosteus aculeatus* L.; and the tidewater goby, *Eucyclogobius newberryi* (Girard). Chironomids quantitatively dominate the bottom fauna and include *Chironomus stigmaterus* Say, *C. attenuatus* Walker, *C. utahensis* Malloch, *C. plumosus* (L.), *Cricotopus* sp., *Procladius* sp., *Tanypus grodhausi* Sublette, and *Tanytarsus* sp. (designated "*Tanytarsus* n.sp. number 121" by Dr. J. E. Sublette, Eastern New Mexico University). The species most definitely associated with the nuisance are *C. stigmaterus*, *C. attenuatus*, *T. grodhausi*, and *Tanytarsus* sp. Other insects include representatives of the families Ephydridae, Corixidae and Notonectidae.

Materials and Methods

The standard ¼-ft.[2] Ekman dredge was used for sampling the substrate when the entire lake was to be surveyed. Ten to fifteen random samples were taken before treatment and afterwards. Each sample was washed in a 28-mesh Tyler Screen (0.589 mm) immediately after collection. The sample was preserved in an individual container for transport to the district laboratory and subsequent counting of larvae.

Water temperatures were obtained with a mercury thermometer (0° to 230°F.) graduated to 2.0. The specific gravity of the water was obtained by using a hydrometer calibrated to known NaCL concentrations at selected temperatures. The calculated salinity is expressed as % salt, to the nearest 0.01% in keeping with the accuracy of the method.

Dilutions of lake water were used to test the salinity tolerances of fish that were being considered for chironomid control. Water collected from the lake in October, 1964, was used without dilution and diluted with tap water to make five different salt concentrations, ranging from 0.58% to 2.29%. The undiluted

TABLE 1 — Results of insecticide applications for control of midge larvae in Lake Dalwigk, Vallejo, California, 1961-1966.

Insecticide	Lb/acre (active)	Season and year of applications[1]	Per cent control of midge larvae after treatment[2] 2 days	10 days	20 days	30 days	40 days	50 days
5% malathion sand core granules	0.5	Fall—1961	100%	100%	100%	100%	100	92
	0.2	Spring—1963	100	100	100	100	100	86
	0.2	Fall—1963	100	100	100	100	100	97
2% fenthion clay core granules	0.2	Spring—1964	100	100	100	100	100	94
	0.2	Spring—1966	100	100	100	100	100	90

[1]No treatments were made during the years 1962 and 1965 because of ecological and naturalistic control studies.

[2]Counts of midge larvae were made from 10 samples (¼ ft² each) during pretreatment and from 10 samples ¼ ft² each) during the postreatment period. Per cent control is based on the total number of larvae in the pretreatment checks which were 681 for 1961, 1117 for spring 1963, 983 for fall 1963, 726 for 1964, and 1147 for 1966.

TABLE 2 — Survival of fish in various dilutions of water from Lake Dalwigk, Vallejo, California, 1964.

	Total salt conc.	Dilution rate — parts tap water/ parts lake water	No. of fish tested for 48-hr. survival	No. of fish surviving at least 48 hrs.	48-hr. survival rate
3.0 - 5.5 inch goldfish	0.58%	3/1 — (used as 1st step in acclimatization — all survived)			
	1.14	1/1	11	11	100%
	1.71	1/3	12	10	83
	2.07	1/9	4	1	25
	2.29	0/1	8	0	0
4.0 - 12.0 inch carp	0.58%	3/1 — (used as 1st step in acclimatization — all survived)			
	1.14	1/1	9	9	100%
	1.71	1/3	10	7	70
	2.07	1/9	3	0	0
	2.29	0/1	2	0	0

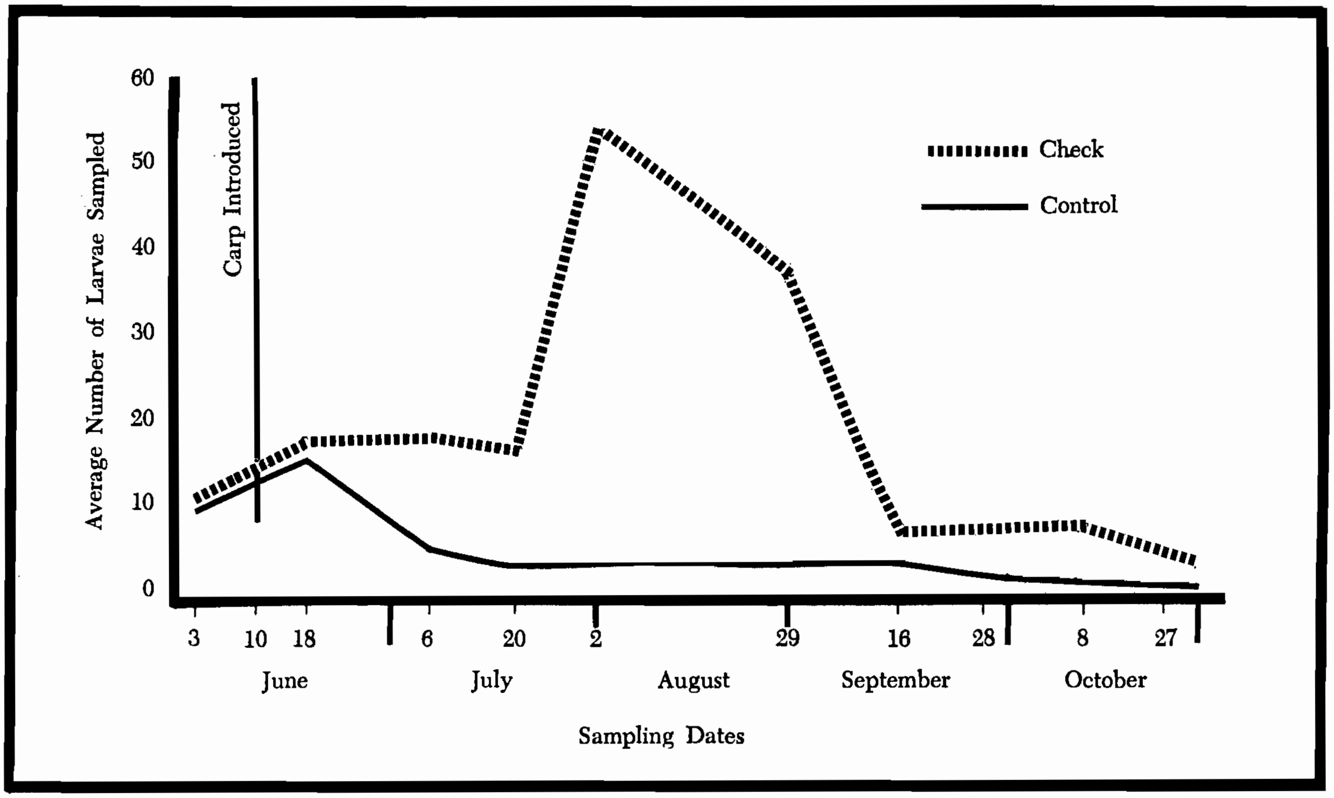

Figure 2 — The effects of carp on the chironomid larval population in a 1/10 acre enclosure in Lake Dalwigk, Vallejo, California, 1965.

water (with a salinity of 2.29% as determined by the hydrometer method) was found to have a chloride concentration of 11,520 mg./1. by titration. The fish were collected from freshwater sources in the county. They were placed in outdoor holding tanks during the experiment. They were exposed gradually to a series of increasing salinities. Any fish surviving in a given salt concentration was kept there at least 48 hrs. before being exposed to a high concentration. The results are expressed as the number of fish surviving for 48 hrs. at a given concentration.

To evaluate the effect of a fish population on immature chironomids a 1/10-acre enclosure was constructed of interlocking, 4-ft.-high, wire fence panels. There was no feasible way to gain entry into this enclosure for sampling, therefore, samples were obtained by reaching over the fence with a core sampler(Spiller, 1965) which collects a sample approximately 1/20-ft.^{2}. Eight random samples were collected bimonthly from within the enclosure, and an equal number were obtained in like manner outside the enclosure. Water samples were concurrently collected for salinity determination.

Observations on Larval Control

Probably the first published record of an insecticide used as a larvicide for chironomids in California concerned Lake Elsinore, Riverside County (Miller, 1951). An 11% BHC wettable powder applied by aircraft at the rate of 1.0 lb./acre gave 94% control. McFarland et al. (1962) used 5% malathion sand core granules (10-20 mesh) applied at a rate of 1.0 lb. (active)/acre produced 90% control in the San Gabriel River, Los Angeles County. One percent fenthion sand core granules were found to provide 76% control by Whitsel et al (1963) when applied to San Mateo County sources at a rate of 0.1 lb. (active)/acre.

In September 1961, random larval sampling in Lake Dalwigk revealed an average larval midge density of 681/ft.^{2}. This was reflected by a large number of complaints received from local residents. These were caused by a massive emergence of *Tanytarsus* sp. On September 15, 1961, a 5% malathion sand core granular (15-30 mesh) formulation was applied at the rate of 0.5 lb. (active)/acre by aircraft (Table 1). Post-treatment larval samples after 48 hrs. were negative indicating apparent 100% control. Observations during this period also revealed considerable mortality of mosquito-fish and threespine stickleback as well as notonectid and corixid species (Hemiptera). In an attempt to refine the control effort and make it more specific for midge larvae the application rate was reduced to 0.2 lb. (active)/acre in 1963. (Table 1). Observations after two separate treatments showed a slight reduction in fish mortality; however, the mortality to the notonectid and corixid populations was as great as that after the initial treatment.

Mulla and Issak (1961) reported a high degree of tolerance by *Gambusia* to the insecticide fenthion. In 1964 and 1966, 2% fenthion granules applied at the rate of 0.2 lb. (active)/acre were used for gnat larvae suppression with success (Table 1). There was still considerable mortality among the notonectids and corixids, but fish mortality was negligible.

Re-infesting midge larvae did not appear in any post-treatment sample until after the 40th day (Table 1).

Observations of Fish

Bay and Anderson (1965) reported effective, short-term control of gnat larvae in water spreading basins by introducing carp, *Cyprinus carpio* L., and goldfish, *Carassisus auratus* (L.), in densities of 150 to 500 pounds of fish per acre.

Lake Dalwigk offers an opportunity to study the effectiveness of fish under considerably different environmental conditions than those described by Bay and Anderson. It was thought that, although forage conditions for carp or goldfish appear to be good, the lake's periodically high salinity might be detrimental to carp or goldfish. It would be possible to control the salinity of the lake to some extent by regulation of the pumping schedule. It was therefore considered advisable to study the tolerances of the two species of fish to the salts in the lake water.

The salinity-tolerance testing was conducted during the fall of 1964. The water collected from the lake to make up the dilutions had an unusually high salt concentration (2.29%). The results of the tests are given in Table 2. None of the fish survived in the undiluted lake water. The greatest salt concentration tolerated by all acclimatized fish was 1.14% (goldfish and carp); the greatest concentration tolerated by any fish was 2.07% (goldfish) and 1.71% (carp). At 48 hrs. the median tolerance level (calculated concentration at which half the fish survive), was 1.92% for goldfish, and for carp it was between 1.71% and 1.92%. These data show that the highest salinity that the carp would probably tolerate without mortality lies within the 1.14% to 1.71% range. Recently Cobey (1966) reported carp occurring in waters having total dissolved solids ranging up to 15,972 p.p.m. (1.5972%).

Futher observations of the tolerance of carp to salinities during the larva suppression study indicated that the fish survived salinities in the lake itself, which then ranged as high as 1.25%.

The 1/10-acre fence was installed in the lake on May 23, 1965. The average water depth during the study (June to October) was 2.5 ft. On June 10, 1965, 40 carp weighing approximately 1.5 lb. each and having a combined weight of 60 lb., which approximates 600 lb./acre, were introduced into the enclosure.

One week after the carp were introduced (June 18, 1965), larval populations in the fence enclosure achieved a peak density inside the enclosure of 15/ft.^{2} (Fig. 2). On succeeding sampling dates larval populations with carp dropped to an average density of less than 5/ft.^{2}. The larval population outside the enclosure increased to a peak density of 54 per sample on August 2, 1965.

Salinities of the lake water during the course of the study ranged from 0.25% (June 3, 1965) to 1.25% (October 27, 1965). To ascertain that there was no mortality of the carp in the fence enclosure, an electric fish shocking device, loaned by the Sacramento area office of the California State Department of Fish and Game, was used in December 1965. All fish that were stocked in the fence enclosure on June 10, 1965, were recovered.

From the results of this study it was decided to stock the lake itself with carp. At the stocking rate of 600 lb./acre, 18,600 pounds of carp would be needed to stock the 31-acre lake. As it was not feasible to collect this quantity, it was decided to collect as many adult female and male carp as possible from various sources within Solano County during the 1966 spring spawning season. Successful spawning should produce the necessary 600 lb./acre of carp within 1 or 2 years. Approximately 2,500 adult carp were introduced into the lake during March, April and May 1966. Traps for juvenile carp are to be placed at various locations in the lake during 1967 to ascertain whether spawning has occurred.

Summary and Conclusions

Application of 5% malathion granules (0.2-0.5 lb./acre) and 2% fenthion granules (0.2 lb./acre) in Lake Dalwigk for midge larva suppression gave an effective control.

Considerable mortality was observed on mosquito fish, threespine sticklebacks, notonectids, and corixids when malathion was used. No appreciable mortality was observed on the fish populations when fenthion was used, but there was considerable mortality to the notonectid and corixid species.

Carp at a stocking rate of 600 lb./acre were found to be very efficient in suppressing midge larvae in a test plot.

Approximately 2,500 adult carp were introduced into Lake Dalwigk during the 1966 spring spawning season. From this introduction it is hoped that the desired 600 lb./acre can be achieved in 1 or 2 years, thus affording a permanent control over the midge larvae.

Acknowledgments

The kind assistance of Mr. Robert Doty and Mr. Gail Grodhaus, California State Department of Public Health, Bureau of Vector Control, in providing technical assistance is gratefully acknowledged.

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THE HELICOPTER AS A NEW TOOL IN THE MOSQUITO CONTROL PROGRAM OF THE MERCED COUNTY MOSQUITO ABATEMENT DISTRICT

ABEL MACHADO, BURTON FENTEM
Merced Co. Mosquito Abatement District
Merced, California
AND
THOMAS D. MULHERN
California State Health Department
Bureau of Vector Control, Fresno

ABSTRACT

This paper briefly describes the mosquito control problem and program of the District, which serves a 2000-square-mile area, located in the mid-portion of the Great Central Valley of California, where a high ratio of mosquito problem to tax base creates a situation which demands the greatest possible economy of mosquito control program. Accordingly, the District has mechanized its operations insofar as possible, by utilizing aircraft as its basic tool for spraying. Residential subdivisions have recently encroached on the agricultural areas about urban centers to the extent that fixed-wing aircraft can no longer be used safely in the vicinity of some of the established residential communities, yet the areas to be sprayed are still so large as to require the use of aircraft; hence the use of helicopters is indicated because of their capability of operating safely in congested areas. Data are presented from a time and motion study which shows that the helicopter could compete favorably with the fixed-wing aircraft in spraying, and could provide additional economical inspection service.

A SAFE AND EFFICIENT MIXING AND LOADING PLANT FOR INSECTICIDES USED IN AERIAL LARVICIDING

WILLIAM F. NORMAN, BURTON FENTEM
Merced Co. Mosquito Abatement District
Merced, California
AND
THOMAS D. MULHERN
California State Health Department
Bureau of Vector Control, Fresno

ABSTRACT

This paper describes a custom-built insecticide mixing and loading station, designed to facilitate the rapid and safe loading of aircraft used to apply insecticides for mosquito control. It was designed and built by personnel of the Merced County Mosquito Abatement District. Provision is made for the mixing of any one of three different insecticides, according to need. There is no bodily contact by the pilot with the insecticides. The average time for mixing and loading 150 gallons of insecticide into the plane is less than 8 minutes.

CALIFORNIA MOSQUITO CONTROL ASSOCIATION ANNUAL BUSINESS MEETING

WEDNESDAY, FEBRUARY 8

STEPHEN M. SILVEIRA, *Presiding*

(Note: A complete report of the C.M.C.A. business meeting has been sent to members. The following is a summary of the minutes of the meeting)

Mr. Silveira: The Annual Business Meeting is now in session. There are 29 Corporate Representatives present.

January 17, 1967
Board of Directors
California Mosquito Control Association, Inc.
1737 West Houston Avenue
Visalia, California

Gentlemen:

We have examined the balance sheet of the California Mosquito Control Association, Inc., as of December 31, 1966, and the related statement of Revenue and Surplus for the year then ended. The foregoing statements were prepared from records kept on the cash basis. Except as noted in the following paragraph, our examination was performed in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other procedures as we considered necessary in the circumstances.

Our examination did not include confirmation or verification of members' dues or other revenues since the Association does not accrue uncollected amounts; therefore, the scope of our examination was limited to recorded cash transactions.

Comments

Cash in Bank:

Commercial $5,683.32 – Amount was reconciled with the bank statements as of December 31, 1966, and confirmed directly with the depositary.

Savings $4,466.64 – Amount was verified by examination of the savings pass book as of December 31, 1966, and confirmed directly with the depositary.

Insurance:

The following was in force as of December 31, 1966 according to the Secretary Treasurer. The policy was examined by us.

Coverage	*Insurer*
Secretary Treasurer	U. S. Fidelity & Guarantee

Policy Number	*Term*	*Amount*
03-71A-66	2/10/66 - 2/10/67	$10,000.00

In our opinion, subject to the preceding qualification, the accompanying Balance Sheet and Statement of Revenue and Surplus present fairly the financial position of the California Mosquito Control Association, Inc., at December 31, 1966, and the results of the cash basis operations for the year then ended in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

We wish to thank Mr. Donald Murray, Secretary Treasurer of the Association for his assistance and co-operation during our examination.

Respectfully submitted,
SIGNED Finch & Janzen
FINCH & JANZEN
Certified Public Accountants

California Mosquito Control Association, Inc.

BALANCE SHEET

December 31, 1966

EXHIBIT A

ASSETS	
Petty Cash	$ .70
Cash in Security First National Bank, Visalia:	
Commercial Account	5,683.32
Savings Account	4,466.64
Fixed Assets (Note 1)	655.05
Total Assets	$10,805.71

LIABILITIES AND SURPLUS	
Sales Tax Payable	$ 5.22
Deferred Revenues (1967 Surplus) (Note 2)	1,810.00
Surplus invested in Fixed Assets	655.05
Available Surplus: (Exhibit B)	
For Administration	4,193.99
For conference activities	4,141.45
Total Liabilities and Surplus	$10,805.71

Note 1: The "fixed assets" consist of a tape recorder purchased in 1961, and an IBM typewriter purchased during 1966. The cost of a filing cabinet purchased several years ago is not known to the present Secretary.

Prepared from records kept on the cash basis.
Issued subject to comments on page one of this report.

Note 2: Pertains to money collected during late 1966 which is properly classified against 1967 revenues.

CALIFORNIA MOSQUITO CONTROL ASSOCIATION, INC.
STATEMENT OF REVENUE AND SURPLUS
For the Year Ended December 31, 1966

EXHIBIT B

	Budget Estimate	General Activities	Conference Activities	Over (Under) Budget
Balance Available, January 1, 1966		$3,205.65	$3,736.25	
Add Revenues:				
Corporate Member Contracts	$ 4,200.00	$4,402.00	$	$ 202.00
Associate Member Dues	300.00	245.00		(55.00)
Sale of Publications	150.00	329.29		179.29
Miscellaneous (Note 1)	100.00	78.42	95.84	74.26
33rd Conference Registrations	3,000.00		1,522.00	(1,478.00)
33rd Conference, Exhibits	1,200.00		2,550.00	1,350.00
33rd Conference, General	360.00		2,534.66	2,174.66
33rd Conference, Proceedings	250.00		175.80	(74.20)
Total Revenues	$ 9,560.00	$5,054.71	$6,878.30	$ 2,373.01
Deduct Expenditures: (Exhibit C)	$12,307.74	$4,066.37	$6,473.10	$ 1,768.27
Balance Available, December 31, 1967		$4,193.99	$4,141.45	

Note 1: $174.26 of the miscellaneous revenues was interest on the $4,292.38 in savings. Since about 55% of the savings represents conference funds, that per cent of the interest is allocated to conference revenue.

CALIFORNIA MOSQUITO CONTROL ASSOCIATION, INC.
STATEMENT OF EXPENDITURES WITH BUDGET COMPARISON
For the Year Ended December 31, 1966

EXHIBIT C

	Budget As Amended	Actual Expenditures	(Over) Under Expended
Administration:			
Advertising	$ 165.00	$ 165.00	$
Communications	500.00	537.24	(37.24)
Office of Secretary	1,200.00	1,200.00	
Office Supplies	250.00	225.18	24.82
Committee Expenses	1,777.00	839.70	937.30
Auditor	115.00	115.00	
Fidelity Bond	150.00	125.00	25.00
Travel Expenses	500.00	293.36	206.64
Contingencies	100.00	83.85	16.15
Total Administration	$4,757.00	$3,584.33	$1,172.67
Capital Outlay:	$ 485.00	$ 482.04	$ 2.96
Total General – Exhibit B	$5,242.00	$4,066.37	$1,175.63
Conference:			
General Expenses	$3,765.74	$3,797.74	$ (32.00)
Proceedings	3,000.00	2,375.36	624.64
Steno Service	300.00	300.00	
Total Conference – Exhibit B	7,065.74	$6,473.10	$ 592.64

Prepared from records kept on the cash basis.
Issued subject to comments on page one of this report.

COMMITTEE REPORTS

Aircraft Committee: No Report.

Bylaws Committee: No Report.

Education and Publicity: Torval M. Hansen, *Chairman*, became seriously ill on arrival at the Conference and could not attend any of the sessions. There was considerable newspaper publicity both in advance of and during the Conference.

Entomology: E. E. Kauffman announced that the next Entomology Seminar would be held at the Voyager Inn outside of Davis, on April 7-8.

Insecticide: D. E. Reed announced that the Committee planned to have the first sections of the Insecticide Manual ready this spring.

Legislative: L. R. Brumbaugh, *Chairman.*

Gentlemen:

The purpose of this committee is to develop needed legislation by drafting, introducing and following through on such related bills in State legislature, as well as keeping apprised of all legislative action which might affect mosquito abatement districts.

In 1966 the goal of this committee was to restore to the State Department of Public Health the authority to carry out mosquito control research and to assist in obtaining a $200,000.00 research allocation for the University of California. The Committee sent letters to the thirteen senators of the State Finance Committee and twenty-one assemblymen of the Assembly Ways and Means Committee, informing these legislators of the need for the research programs. Meetings were held with the legislative analyst, Division of Finance, and the Chairmen of the Senate Finance Committee and Assembly Ways and Means Committee to try to convince them of the necessity for these research programs. Many members of the C.M.C.A. appeared at the hearing of the Assembly Ways and Means Committee, and we were successful in having this Committee restore to the State Health Department the authority to conduct a research program. However, the Senate Finance Committee recommended that only $30,000.00 be appropriated to the State Department of Public Health to implement mosquito control research and the remaining funds transferred to the University of California. The final decision of the legislature was to accept the recommendations of the Senate Finance Committee and to allocate $100,000.00 in new funds to the University of California. The funds approved for mosquito control research for the year of 1966-67 are as follows; State Department of Public Health, $30,000.00; transfer of funds from the State Department of Public Health to the University of California, $115,000.00; and new funds to the University of California, Division of Agricultural Science, $100,000.00, for a total of $245,000.00. Legislature approved the expenditure of $200.000.00 for the University, but only appropriated $100,000.00, with the suggestion that the remaining balance be obtained from other sources.

The C.M.C.A. Legislative Committee wishes to thank the members of the Association, University of California and the Department of Public Health for their assistance and guidance in legislative matters during this past year.

Source Reduction Committee: Robert H. Peters, *Chairman.*

The Source Reduction Committee met several times during the year in an effort to cope with matters of concern.

The two main accomplishments were: (1) circulation of a questionnaire intended to re-evaluate and clarify information received relative to summaries on source reduction; and (2) modification of the Source Reduction Form for more meaningful reporting.

It is recommended by this committee that the following matters be given priority during the ensuing year:

1. That the Bureau of Vector Control Consultant on Source Reduction be asked to review information received for summary in order that errors and omissions can be eliminated before publication.

2. That effort be made to summarize the effects of source reduction in terms of dollars, in order that a true justification can be acknowledged.

3. That determination be made as to where "weedicides" fit into mosquito control programs.

4. That a panel type program on the justification of weedicide activities be considered for the 1968 Annual Conference.

Operational Equipment and Procedures: S. M. Silveira, *Chairman.* The 1967 annual equipment show will be held in Tulare on March 31.

Proceedings: W. D. Murray, *Chairman:* Publication of the 1966 Proceedings was delayed, a regrettable, but unavoidable fact. They have been distributed to all 1966 Conference registrants, one to each Associate Member, and two to each District. More are available to Districts on request.

Publications: W. D. Murray, *Chairman:* We have run out of the Mosquito and Gnat Guides and are low on the Fly Guide. We plan to reprint them soon. The Fish Guide should be available this year, as well as the Insecticide Manual. The Chironomid Midge paper by Saul Frommer should be run off within the next few weeks.

Research: J. H. Kimball, *Chairman:* The primary objective of the 1966 Research Committee was to make available to all Mosquito Abatement Agencies in California source material that would be helpful to each agency in preparing its individual requests to its local Senator and Assemblymen urging that the authority and the necessary funds be restored to the State Department of Public Health to reestablish the mosquito control research program by the Department's Bureau of Vector Control.

The above objective was successfully accomplished by mailing detailed source material to all District Managers on two occasions. The first mailing was by the Chairman's memo dated February 24, 1966 just prior to the hearings by the Assembly Ways and Means Sub-Committee and the Senate Finance Sub-Committee which were held on March 2 and March 15, respectively. The memo transmitted a sample letter to a State Legislator, copies of the resolutions adopted by this Association, by the League of California Cities and by the County Supervisors Association, as well as a copy of the original "Joint Report of the State Department of Public Health and the University of California on Mosquito Control Research."

The second mailing, containing additional source material, was by the Chairman's memo of April 22, 1966, in anticipation of a meeting by the Legislative Joint Conference Committee to negotiate the differences between the recommendation of the Assembly Ways and Means Committee and those of the Senate Finance Committee. These recommendations follow:

Assembly Ways and Means Committee: Recommended full appropriation of $145,815.00 to the State Department of Public Health with full authority to carry out research as practiced prior to July 1, 1965.

Senate Finance Committee: Recommended that only $30,000.00 be appropriated to the State Department of Public Health to implement mosquito control research developments and that the remaining $115,815.00 be transferred to Item 107 of the University of California Support Budget.

The final decision of the Legislature was to accept the recommendation of the Senate Finance Committee and, in addition, to allocate $100,000 in new funds to the University. The funds approved for mosquito control research for Fiscal Year 1966-67 were allocated as follows:

Retained by the State Department of Public Health		$ 30,000.00
Transferred to the U. of C. Division of Agricultural Sciences		$115,815.00
Part for Fresno Research Program	$83,315.00	
Part for U. of C. School of Public Health, Berk.	$32,500.00	
New Funds to U. of C. Division of Agricultural Sciences		$100,000.00
Total		$214,815.00

The six members of the Research Committee met at Lodi on August 4, 1966 with C. F. Kelley, John E. Swift, Ray F. Smith and A. Ralph Barr of the University of California and Richard F. Peters, Jack R. Walker and Thomas D. Mulhern of the State Bureau of Vector Control. Our late President, Oscar V. Lopp, and our Acting President, Stephen M. Silveira, were also present. The purpose of the meeting was to review the proposed research program by the University and to determine support activities by the Association that would facilitate the University's mosquito control research efforts.

At the conclusion of this meeting, one specific job requiring immediate action by our committee was indicated by the repeated invitation from the U. of C. representatives for recommendations on the research projects to be carried out at the Fresno Station under the direction of Dr. Ralph Barr. Dr. Ray Smith clearly indicated that (1) the research must be limited to the available $82,000.00; (2) the research will be clearly "problem oriented"; and (3) the proposed research program must be prepared by Dr. Barr within several weeks for review and approval by the University's Advisory Committee (with Dr. Smith as Chairman) and then by the Joint Research Coordinating Committee of the State Department of Public Health and the University of California on Arthropods of Health Importance.

In response to this request, the Committee Chairman prepared a summary of the Recommendations of the 1964 Research Committee as compiled by its Chairman, Gordon F. Smith, from a detailed canvass of C.M.C.A. membership on the research needs of this particular area. This summary was distributed to committee members on August 8, 1966 with the request that they individually submit their recommended list of top priority research projects directly to Dr. Barr because of the critical time factor.

The Committee Chairman attended the tenth meeting of the Joint Committee of the State Department of Public Health and the University of California on Arthropods of Health Importance held at Berkeley on September 27, 1966. At this meeting, the Joint Committee approved the following general plan for mosquito control research by the U. of C. Division of Agricultural Sciences.

"A" Projects: Those centered at Fresno, essentially of a problem-solving nature—to be headed by Barr with multi-technician support, including:

(1) Continuation of the U.S.D.A. grant on pathogenic parasites of mosquitos on a temporary basis.

(2) Cultural methods for mosquitos – to continue the maintenance of existing colonies for the numerous diversified needs.

(3) Biology and control of pasture mosquitos – review of the literature and resumption of research on *Aedes nigromaculis* ecology and control possibilities.

(4) Eradication of *Culex pipiens* by cytoplasmic incompatibility – continuation of promising research under way.

"B" Projects: Those located on the several campuses – at present eligibility criteria are being developed. The campus allocations follow:

(1) U. C. Davis – $31,000.00 for the rice field mosquito project devoted to studies of mosquito behavior and prevention by rice field management. This allows for an academic appointment (Washino), one technician, and support funds. A small amount is going to Agricultural Engineering to continue equipment development activities.

(2) U. C. Berkeley – $33,000.00 divided between the Division of Parasitology for addition of one academic staff, probably for work on nutritional approaches to mosquito control, and the Division of Biological Control for one academic staff to explore the use of invertebrate predators of mosquitoes.

(3) U. C. Riverside – $26,000.00 to augment Mulla's insecticide studies, providing one academic staff, one technician and support; and $10,000.00 to Biological Control to reinforce activities of Bay on vertebrate predators, and E. Reeves on pathogenic parasites. The University committee indicated that additional funds were required to support these projects and had urged that supplemental funds be procured from other sources.

It is recommended that the 1967 Research Committee, through its individual members, establish a direct liaison with each of the above described research projects and prepare a report on the objectives and progress of each project for distribution to all members of the association. It is also recommended that the 1967 Research Committee continually determine the current critical research needs of the Association Membership and prepare an annual evaluation of the research work under way in terms of meeting the present and future needs of the Mosquito Control Agencies.

Yearbook: J. H. Kimball, *Chairman.* The 1966 Year Book was mailed on April 26 to all individuals and organizations named within its covers and the itemized distribution list was filed with Secretary W. D. Murray. The cost of printing was $649.12 plus mailing cost of $39.84 for a total expenditure of $688.96.

The Year Book Committee extends its apologies to the American Mosquito Control Association for the unintentional omission of the information on membership and Mosquito News as submitted each year by Executive Secretary T. G. Raley. It was too late when we discovered that page 52 was completely blank – the page we reserve each year for the AMCA.

The actual printing cost should have been about $780.00 because ten complete pages, including the revised Bylaws, required resetting of the type. Because of the omission of page 52, however, the printers set the cost the same as for the 1965 Year Book.

The Chairmen of the Committee on Aircraft, Insecticide and Weedicide, and on Source Reduction, have been requested by letter, dated November 16, 1966, to advise the Year Book Committee by December 19 of any changes in the statistical data they wish reported by each agency in the 1967 Year Book. The annual three page Year Book questionnaire will be revised accordingly and mailed to all agencies by December 30, 1966.

The Year Book Committee respectfully requests the Board of Directors to advise the Committee of any additions, deletions or changes in the format for the 1967 Year Book.

It is the Year Book Committee's recommendation that the Association budget $800.00 for the 1967 Year Book.

Federal Legislative Bill HR3896: J. W. Bristow: Glenn Stokes, AMCA Legislative Committee Chairman, has presented to AMCA a detailed review of this bill which was introduced by Congressman Boggs. This bill proposes to increase research funds and to provide subvention funds for actual operation of districts. The analysis of this bill by the AMCA Legislative Committee indicates a need for extensive modifications by mosquito control people.

The objectives of the bill are very good as far as research funds are concerned. The only thing we can do is ask for a hearing in the House Committee. We should offer our services. Mr. Pratt, the new President of AMCA has assured me that the Association will not take any action which might offend Congressman Boggs, who by introducing this bill twice, has certainly shown that he is a friend of mosquito control, regardless of the motives which some people may give to his actions. We may ask him to modify the bill; we may ask him to let us help him. We should be sure to praise him for those items which are good.

Resolutions: Gardner C. McFarland, *Chairman.*

I move the adoption of the following resolutions:

1. Be It Resolved by the California Mosquito Control Association, Incorporated, assembled at its 35th Annual Conference together with the American Mosquito Control Association, Incorporated, at its 23rd Annual Meeting held at San Francisco, California, February 8, 1967, that the members do hereby express our thanks to the San Francisco Convention and Visitors Bureau for their services and special interest of their Assistant-Manager, Miss Judy Secunda.

2. Resolved that we the members hereby express our thanks to C. Donald Grant, E. Chester Robinson, Howard R. Greenfield and to the other members of the Local Arrangements Committee for their great contributions to the success of this Conference.

3. Resolved that we the members hereby express our appreciation to the management of the Sheraton-Palace Hotel and particularly to the Sales Manager, Jim Manion for the very fine services and assistance rendered.

4. Resolved that the California Mosquito Control Association hereby express its thanks to the Sustaining Members and Commercial Exhibitors, with special acknowledgement of sponsorship by Kaiser Jeep Sales Corporation of the Hospitality Hour; of American Cyanamid Company sponsorship of coffee service, Ladies Social Room and hospitality room; of Chevron Chemical Company for the special hospitality room.

5. Resolved that we the Members hereby express our sincere appreciation for the successful program efforts of James W. Bristow, Thomas D. Mulhern, Richard F. Peters and other members of the joint Program Committee of AMCA – CMCA.

6. Resolved that we the Members hereby express our sincere appreciation to the Officers and Committeemen of this Association for their fine work during the year.

7. Resolved that we the Members hereby express our thanks for the support and continuing interest of the Trustees as evidenced by the Trustee Corporate Board Chairman Fred De Benedetti and other Members representing all areas of California.

8. Resolved that we the Members hereby express our sincere appreciation to the Officers and Committeemen of the California Mosquito Control Association and American Mosquito Control Association for their fine work during the year which has culminated in the most successful Conference of all time.

9. Resolved that the California Mosquito Control Association hereby expresses its appreciation to the several organizations which donated gifts for distribution to those in attendance and include the Castroville Marketing Association of Monterey County; the S&H Green Stamp Company; Rathjens Distributors, San Francisco; H. D. Hudson Company. Piper Aircraft Corporation; Wente Brothers Winery; Cresta Blanca Winery; Weibel Winery; California Raisin Associa-

tion; Christian Brothers Winery; J. D. Martin Ranch (oranges).

10. Resolved that we the members request that the President and Secretary take the necessary steps to communicate the actions taken by this Assembly to the several parties recognized.

The motion to approve the Resolutions was duly seconded and passed.

J. W. Bristow: I would like to move that we add the name of Gardner McFarland for his work in helping to organize this Conference. This motion was duly seconded and passed.

R. H. Peters: I move that all the actions of the Board of Directors and of the Association during the past year be accepted by the Association as a whole at this meeting. Duly seconded and passed.

S. M. Silveira: We have received a petition to elect Oscar V. Lopp to Honorary Membership in this Association. The petition originated in the Northern San Joaquin Region.

L. R. Brumbaugh: The procedures as required by Bylaws have been fulfilled.

I move that Oscar V. Lopp be made an honorary member (posthumous) of the CMCA and that the necessary papers be prepared. Duly seconded and passed.

Ways and Means Committee: Gardner C. McFarland, *Chairman.*

The Ways and Means Committee met twice during 1966, April 21 and December 1. A number of suggestions and recommendations were fully studied by several subcomittees at the meetings and by frequent correspondence. These included

John Brawley — Study and recommendations for Certification of mosquito control personnel.

Les Brumbaugh — All details and cost of lapel pins.

Paul Jones, Melvin Oldham, Chester Robinson — Recommendations for the Operational Manual.

William Rusconi — Recommendations as to technical correction of By-laws.

Gordon Smith, Kenneth Whitesell, and Joe D. Willis — Suggestions as to possible formation of a technical CMCA Association and the possibility of the CMCA operating as a chapter of the AMCA.

Gardner C. McFarland and James St. Germaine — Preparation of a model Certificate of Recognition for Past Presidents with all attendant costs.

Actions taken during the year:

1. *Operational Manual.* It was recommended to the CMCA Board of Directors, that the University of California and State Health Department be asked to prepare an operational manual for mosquito control agencies in California. The Board referred this matter back to Ways and Means for further study.

2. *CMCA Pins.* The Committee recommended to the Board that CMCA pins as shown by Lester Brumbaugh be provided for sale to members. The Board approved procurement of suitable pins through Lester Brumbaugh. The pins are to be sold at cost so that eventually the entire costs of the pins will be covered.

3. *By-Laws.* No recommendations were adopted.

4. *Formation of a Technical CMCA Association:* General discussion was held on the possibility of forming a technical section of the CMCA in relation to establishing a chapter within the AMCA. This concept will be studied further in 1967.

5. *Certification of Mosquito Control Personnel.* John Brawley submitted a comprehensive report and recommendations to the Committee. The Committee recommended to the Board that it appoint a special committee to provide definite recommendations to the CMCA Ways and Means Committee within six months. The Board referred the matter back to the Ways and Means with the instruction that John Brawley refine current recommendations for consideration of the Board within 6 months.

6. *State Aid to Mosquito Control Agencies.* A variety of viewpoints precluded any definitive recommendations. This matter will again be brought up for consideration before the Committee in 1967.

7. *Code of Ethics.* After much discussion, no consensus was reached so the subject was dropped.

8. *Certificate of Recognition for Past Presidents.* It was recommended to the Board that necessary arrangements be made to provide all past and future Past Presidents with an appropriate certificate of appreciation. The Board included the recommendation in the 1967 budget with budget set at $170.00.

9. *Damages Caused by Mosquito Control Operations.* The Board charged Ways and Means with the responsibility for this study and preparation of a suitable questionnaire to be provided all mosquito control agencies in California.

Nominating Committee: R. H. Peters, Chairman. The slate of officers selected by the Nominating Committee are:

President: Stephen M. Silveira
President Elect: James W. Bristow
Vice President: James St. Germaine

G. C. McFarland moved that these nominees be elected by unanimous ballot. R. H. Peters seconded and a unanimous vote was recorded.

Regional Representatives: The respective regions reported their selections for Regional Representatives:

Southern California Region: Norman F. Hauret
Alternate: Frank Small

Southern San Joaquin Valley Region: Dennis Ramke
Alternate: Richard F. Frolli

Northern San Joaquin Valley Region: Lester R. Brumbaugh
Alternate: Robert H. Peters

Sacramento Valley Region: Eugene E. Kauffman
Alternate: Melvin L. Oldham

Coastal Region: John H. Brawley

The Coastal Region did not designate an Alternate. Originally, James St. Germaine had been selected as the Regional Representative, with John Brawley as Alternate. With the election of James St. Germaine to Vice President, John Brawley was advanced to Regional Representative, and his position of Alternate was left open.

Trustee Corporate Board: Fred DeBenedetti reported that the Board positions had been filled. He noted that the Trustees had decided that a Trustee should serve for a term not to exceed 2 years. Two of the present trustees have been selected for 1 year terms, three will have 2 year terms.

The selections are: Fred DeBenedetti, of the Northern San Joaquin Valley Region, Chairman. Wm. S. Brown, of Southern California Region, Vice Chairman. Marion C. Bew, of the Sacramento Valley Region. Jack W. Chezick, of the Southern San Joaquin Valley Region. A. H. Sagehorn, of the Coastal Region.

New Business:

A. S. Steiner: I would like to announce that Jack Kimball has been sent by W.H.O. to Venezuela, and then to Geneva, Switzerland, where he is helping to write a manual of world-wide scope on mosquito larviciding. He sends his regards to you.

E. D. Davis: The Southern San Joaquin Region extends an invitation to C.M.C.A. to hold its next meeting in that region – preferably at Fresno, where we have good facilities in the Hacienda Hotel complex.

GENERAL SESSION

WEDNESDAY, FEBRUARY 8, 1:30 P.M.

GEORGE T. CARMICHAEL, *Presiding*

SPRAY ATOMIZATION, APPLICATION VOLUME AND COVERAGE

NORMAN B. AKESSON AND WILLIAM E. BURGOYNE
University of California
Department of Agricultural Engineering
Davis, California

The close relationship between the factors of spray particle size, total volume applied, type of spray coverage required, and the loss of small but significant amounts of spray to adjacent crops, wildlife areas, or human habitations is of particular significance to vector control specialists who have led in introducing low volume applications of less than one gallon per acre.

Regardless of how the rates and dosages used in vector control by aircraft and ground equipment compare with those in commercial applications, both types of operations use essentially the same techniques and devices for breaking up a liquid.

ATOMIZERS

There are many techniques and devices that have been developed for breaking up a liquid into the small drops necessary to obtain coverage on plant surfaces for chemical pest control. All of these require an input of energy to overcome the molecular tension that holds a liquid together and creates the tremendously expanded surface of millions of small drops.

The most frequently used devices are the hydraulic pressure nozzles shown in Figure 1, which are identified according to the type of droplet pattern that they produce:

1. cylindrical jet, which ejects liquid from a small circular orifice;
2. hollow cone, created by a small whirl plate ahead of the orifice which gives the spray a tangential spin, thus spreading and breaking up the liquid;
3. another form of the hollow cone in which the tangential spin is produced by an offset entrance to the whirl chamber (frequently described as "nonclog nozzles");
4. full, or solid cone produced by drilling a small hole in the center of the whirl plate to fill in the normal hollow cone;
5. flat fan, wherein proper milling of the orifice slot gives a long narrow pattern; and
6. flooding nozzle, which uses simple impaction of liquid against a sloping plane to produce a coarse fan-type pattern.

Each of these designs has been used for pesticide applications and is adapted to a particular service primarily on the basis of the coarse or fine spray it produces. Nozzle (1) is used for a coarse, low drift and also for low coverage type application (low numbers of large drops on a given area of plant surface), often used for 2,4-D or other hormone herbicide applications by aircraft. The hollow cone (2) and flat fan (5) are probably the most commonly used of the group with the greatest flexibility available in (2) where combinations of whirl plate and disc orifice size can be used to obtain a wide range of spray particle sizes. Number (4) gives a distinctly coarser spray from the center jet portion which may be undesirable, while number (6) is used for extremely coarse atomization, with a minimum amount of spreading required by ground operated equipment for spraying of 2,4-D type sprays in certain vineyards or under other uniquely hazardous operating conditions.

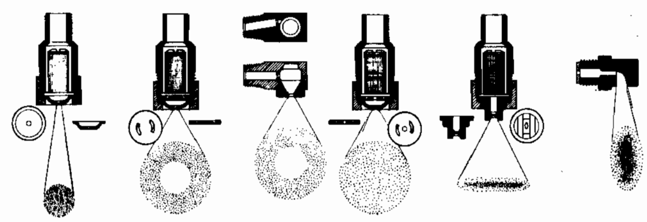

Figure 1 — Hydraulic pressure nozzles.

The spray patterns from fan nozzles are shown in Figures 2 and 3, which show the spray atomization as relatively coarse in Figure 2 and considerably finer in Figure 3. This is the result of merely increasing the pressure in Figure 3. Note the liquid emitting first, as a surface sheet and then spreading into ligaments which finally break into myriads of various size droplets. The vertical line in the upper right is a common pin which is approximately 840 microns diameter. It takes 25,400 microns to equal one inch. It can be seen that there are many different sizes of drops produced, and their size can be compared to the pin.

Some of the other types of atomizers used in chemical application are the air shear(Figure 4) and the many spinning brush, screen and disc types both air (propeller) and electric motor powered. Some of these are shown in Figure 5 with a close-up of a spinning multiple disc type shown in Figure 6. The air shear Figure 4 type functions by spreading the liquid on the surface of a plate and then blowing the liquid off the edge of the plate causing it to be broken into drops. The spinning devices atomize liquid by utilizing centrifugal force to "spin" liquid off a plate or through a

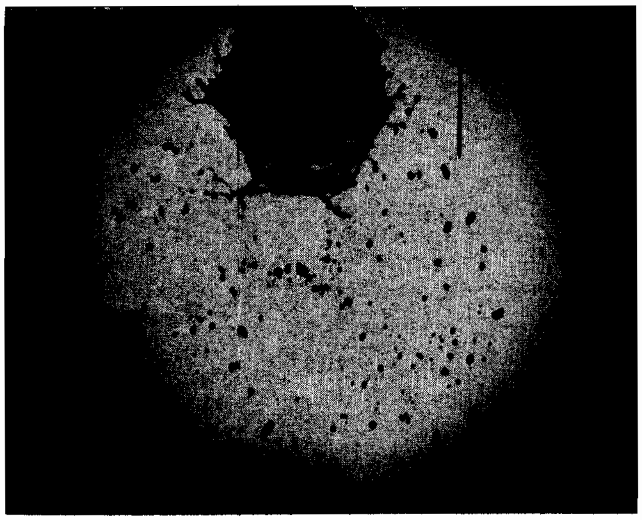

Figure 2 — Fan nozzle spray pattern

screen or perforated cylinder. The process is shown in Figure 7 which also shows the comparatively fine spray atomization that the spinning devices are capable of producing. On the other hand a very coarse spray can be produced by a spinning orifice system as shown in Figure 8 where an extremely viscous liquid is being emitted from a cylindrical jet on the periphery of a spinning hollow disc.

It is most notable to observe that in all of the nozzles shown a wide range of drop sizes, or diameters, are produced. The spinning disc, very carefully adjusted, will give two sizes of drops; one, the primary size, and two, a satellite drop which as close examination of Figure 7 will show, comes from the necking down and eventual breaking of the filament between two primary drops. Techniques and machines for producing single size drops under laboratory conditions are available.

Figure 3 — Fan nozzle spray pattern, with increased pressure.

Microburettes and various adaptations of these fitted with vibrators on the needles to produce a timed impulse will break the liquid stream from the needle into a single drop size spray. But other than these unique systems, we know of no commercial atomizers in use in chemical pest control that will significantly narrow the drop size (diameter) range or reduce the spectrum of spray droplets as will the basic hydraulic nozzles of Figure 1.

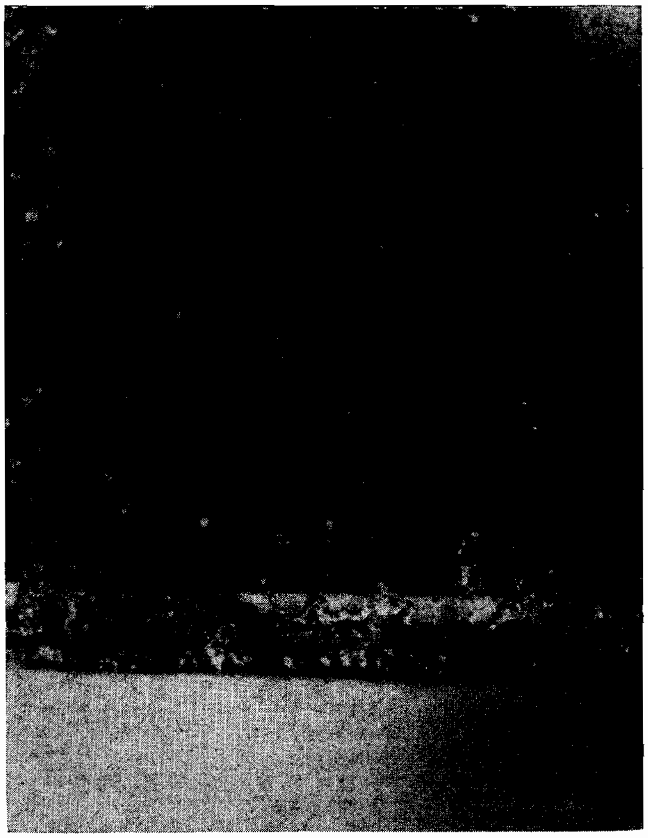

Figure 4 — Air shear spray pattern.

Spray Drop Diameter Range

Since the spray from any atomizer is composed of a wide range of sizes, it is necessary to devise some means for expressing this range so as to identify the spectrum produced. A simple frequency table is usually first set up which breaks down the size (diameters) range into convenient classes, with the numbers observed in each of these classes. The frequency table in itself expresses the drop size range and numbers, but is cumbersome to use to compare various size ranges as, for example, from different nozzles. The data can now be graphed and Figure 9 illustrates such a size range, drop frequency presentation. The lower scale of Figure 9 indicates drop size in microns and the vertical scale is in percent of drops at a given size.

At the apex of the first or 30 psi curve it can be observed that 35% of the drops are in the 100 micron

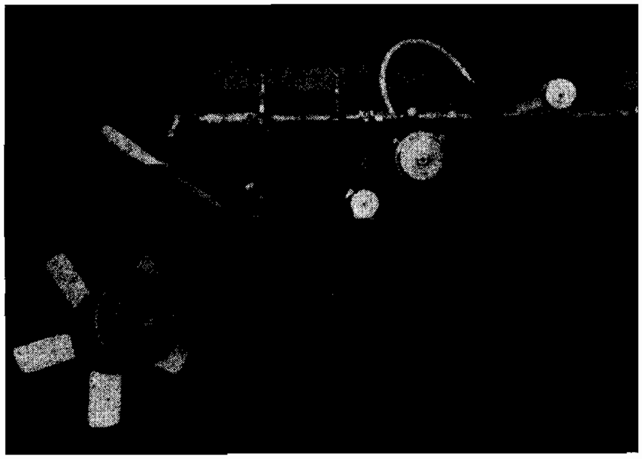

Figure 5 — Types of atomizers used in chemical application.

Figure 6 — Spinning multiple disk atomizer.

class. However, such a graphical presentation places an undue emphasis on drop frequency which may not be where emphasis belongs. Thus, other weighted means are used to express atomization spectrum. Probably the most common of these in the area of pest control work is a presentation based on volume rather than diameter. This might have been similar to Figure 9 but with volume range units instead of diameters. However, more descriptive graphical plots can be designed to better illustrate the spectrum produced.

Such a presentation is shown in Figure 10. Here each curve or line illustrates the volume drop size range produced under the given atomization conditions. The vertical scale is of the drop sizes (diameters) in microns and the horizontal scale is a probability scale which is read in cumulative percent of the drop volume. A reading across from any drop size, such as 100 microns, intersects a given curve, such as the solid line (Univ. 8002). Dropping from this point to the lower scale indicates 1% of all the spray volume produced by this nozzle will be in the 100 micron and lower diameter classes.

Certain statistical models are obviously being portrayed by these graphical presentations. Figure 9 resembles a well-known type of graph which, if symmetrical about a given central value or mean, would be called a normal distribution. However, as can readily be seen the drop spectrum is not symmetrical but slightly skewed, changing somewhat as the pressure in the nozzle was changed. These then are called skewed distributions. Now, referring back to Figure 10, if the data were a normal distribution it would plot a straight line on linear (vertical scale) probability (lower cumulative scale) graph paper. Because the data are not normally distributed but are skewed, the vertical scale is logarithmic with the lower remaining cumulative-probability. This type of graphic presentation should aid in making the data plot as straight lines.

Certain averages are frequently used to express all of the data in one number. The simplest of these is an arithmetic mean which is expressed as $\Sigma ND/$

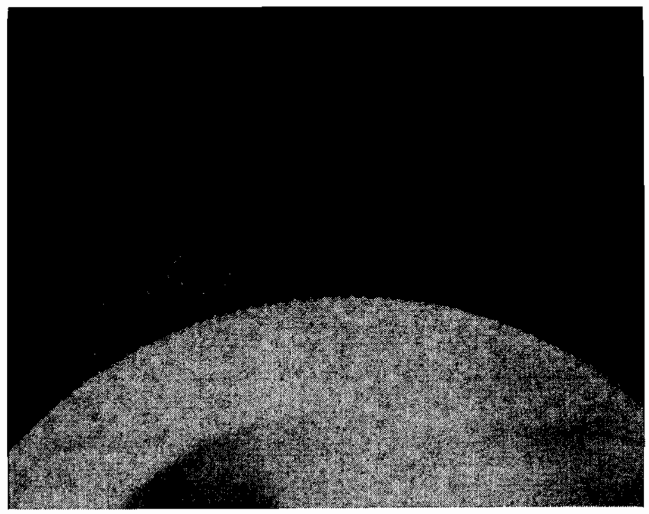

Figure 7 — Spinning device producing fine spray.

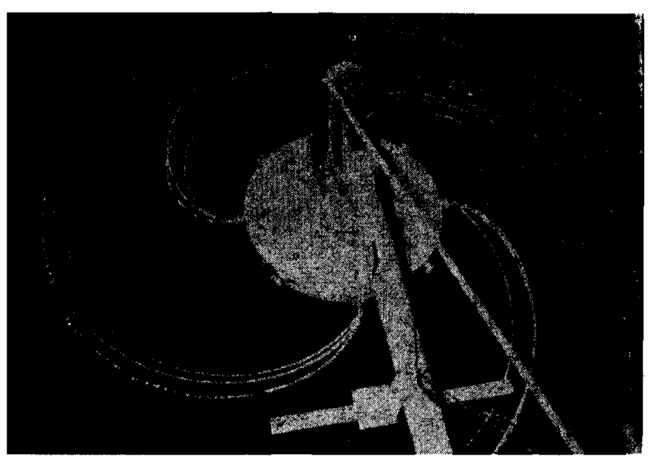

Figure 8 — Spinning device producing coarse spray.

ΣN, or summation of frequency times class diameters divided by summation of all drop frequencies. The median diameters can be defined as the value (size) that divides the total numbers (or volumes) of drops into two equal groups, are half above and half below the median. On the lower scale of Figure 10 can be seen this halfway or 50% point which, if followed up to the curves and thence to the left scale, will give the volume median drop size for each curve. It is important to note that much more information can be obtained from the graphical data, and frequently the single number means or median is misleading.

Spray Atomization Data

We can now examine the data presented in Figures 10, 11 and 12 and see how these relate to the use of certain atomizers and to the practical operation of an aircraft sprayer for a specific job. Figure 10 illustrates the drop size spectrums obtained from several flat fan type nozzles and one hollow cone type. The data is from four observers and shows general agreement in slope of the curves and drop size spread as a function of:

1. placement of the nozzle discharge in an air stream at different angles (first two curves);
2. a higher nozzle pressure for number three (100 psi compared to 40 psi for all others); and
3. discharge into still air for the last three, as well as use of water instead of oil for spray liquid.

As would be expected, the nozzle directed with the air stream (100 mile per hour air velocity) gave coarser drops (solid line curve is above others) than the nozzle placed at right angles to the air stream. In VMD (volume mean diameters) this is about 350 microns versus 270. The Tate fan and cone nozzles were smaller in size and although operated at the same pressure but with water spray gave lower drop size spray spectrum or VMD of approximately 180 and 165 microns,

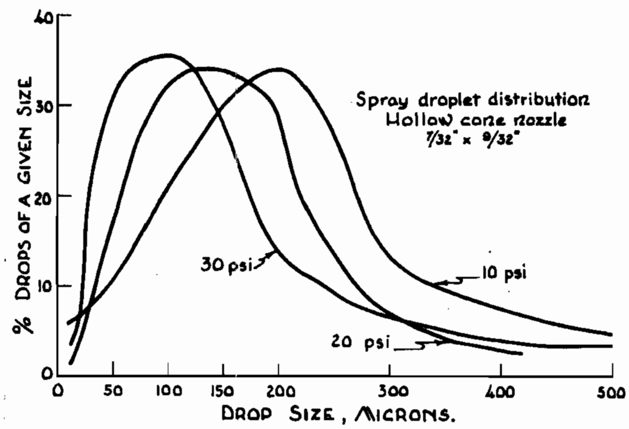

Figure 9

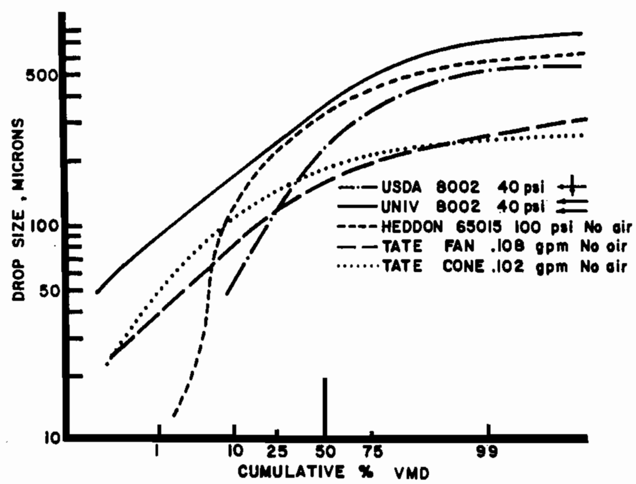

Figure 10

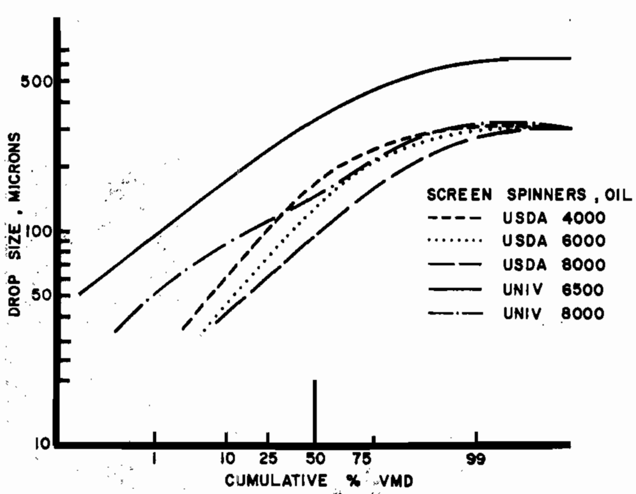

Figure 11

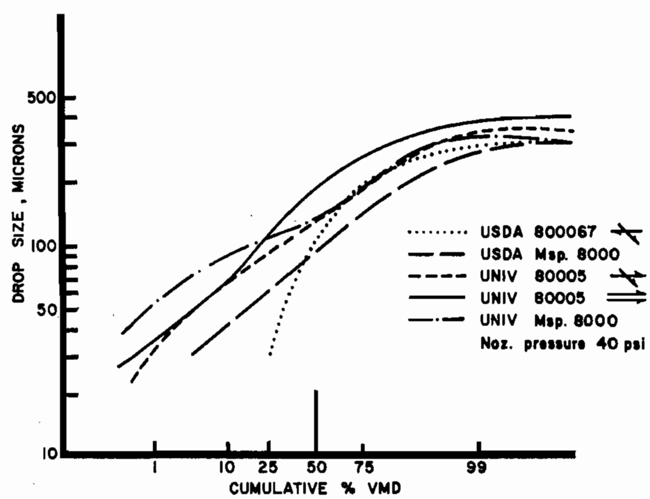

Figure 12

Figures 9, 10, 11, 12 – Graphic presentations of drop size and frequency of various pieces of equipment.

respectively. It is interesting to note that the general character, slope and curve are about the same for all of these with the exception of Heddon, number three. The 65015 fan nozzle is somewhat smaller than the 8002 but the 100 psi (pounds per square inch) placed the VMD at about 280 microns or between the two 8002 nozzles. More importantly, an anomaly exists in the manner in which the 65015 curve drops rapidly on the left, indicating a high proportion of small drops in the spectrum. The U.S.D.A. 8002 also drops slightly, giving rise to this same observation.

Since the observation of drop spectrum requires a complex and tedious technique, it is difficult to check one observer's data against another's. This has led to differences of opinion as to the significance of such data anomalies as are shown in Figure 10. Further importance of this can be seen by examining Figures 11 and 12. Figure 11 shows similar curves obtained from several spinning screen devices with observations from two groups being recorded. Liquids used were light oils and the slope and general character of the curves is quite consistent. As would be expected, the higher the velocity of the spinner the finer was the spray atomization. However, the two observers disagreed on the fineness of spray with the U.S.D.A. data generally finer than comparable data from University observation (spinner type, velocity and liquid were the same).

It should be noted that U.S.D.A. data were all taken in field trials while all other observers took data within laboratories or closed buildings. It would seem that the latter would be desirable in that perfect weather conditions for catching drops in open atmosphere would be difficult to find. The fact of smaller drop size observed by the U.S.D.A. group is another anomaly in the data gathering process.

Figure 12 combines several spinner and fan nozzle curves from which it can be seen that agreement exists in the general slope and character of all except the U.S.D.A. 800067 nozzle. This particular nozzle directed a few degrees below the oncoming air stream gave a VMD of about 128 microns, but more significantly it

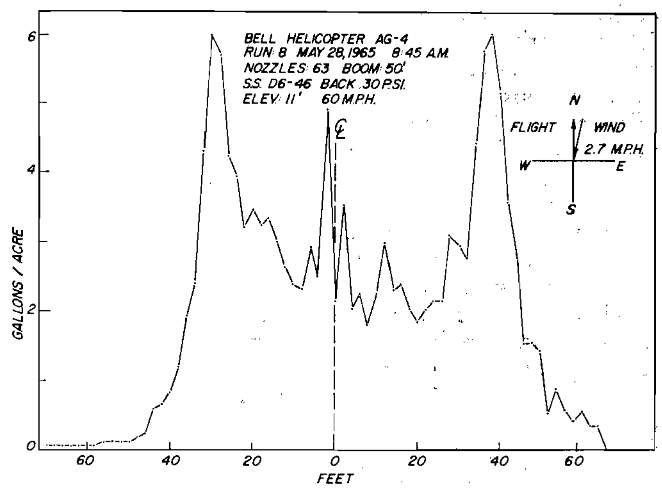

Figure 14

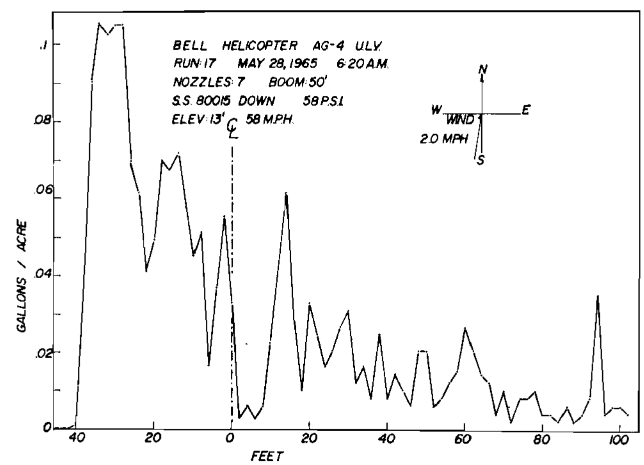

Figure 15

Figures 14 and 15 – Effect of atomization on spray coverage.

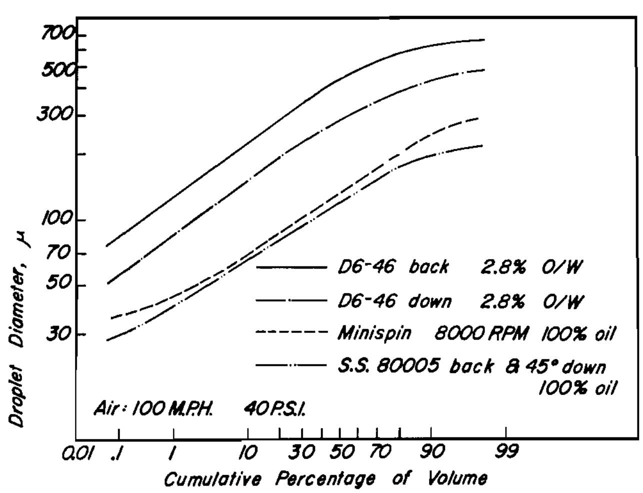

Figure 13 – Drop size and frequency from cone type nozzles.

dropped rapidly on the left, indicating a preponderance of very small drops. The observer's conclusion was that spinning devices gave narrower drop size spectrum ranges than did the flat fan nozzles. It might appear that the fans used for comparison were uniquely capable of very fine spray production and the spinners were generally consistent (between observers) and in agreement with other fan and cone nozzle data. This then points up the differences that exist in data collection and makes obvious the need for greater coordination and standardization of data taken from drop size measurements.

Figure 13 shows data in similar form for coarser sprays obtained from cone type nozzles with 6/64 inch orifices and number 46 (coarse) whirl plates. Variation in VMD can be seen as nozzles are altered in direction to the airstream. These relatively coarser sprays are widely used for general insecticide and fungicide applications. Extremely coarse sprays would be produced by the jet nozzles aimed with the air stream, or by use of viscosity additives. These are used for 2,4-D or other hormone type sprays on brush control and in certain crop areas where drifting chemical may cause serious damage. Figures 14 and 15 show the effect of atomization on spray coverage. As spray atomization is made finer, the swath coverage from a given aircraft becomes wider as the fine spray is more influenced by the aircraft wake. The very fine and low volume (1 pint/acre) spray pattern of Figure 15 is typical of that obtained from an aircraft, in this case a Bell Ag-5 with a 50-foot boom. Even with very low wind velocity (small side component) the pattern is distorted and produces a long downwind tail. Successive laps across a given field are expected to "fill in" and make more uniform such a pattern. However, it is easy to see how skips and poor results could result from low volume applications.

Figure 16 shows a swath produced by 4 spinning disc atomizers, which produce an extremely fine spray. However, the wind was calm and the 150-foot swath was not displaced as badly as shown in Figure 15.

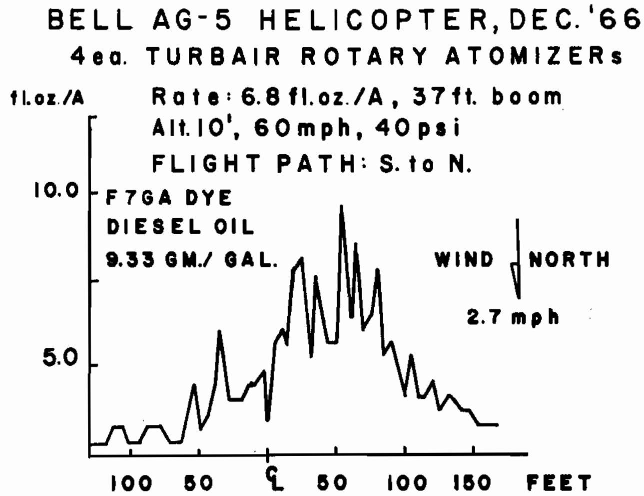

Figure 16 – Swath produced by spinning disk atomizers.