OPERATIONAL INVESTIGATIONS DEALING WITH MOSQUITOES IN CALIFORNIA [1]

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INTRODUCTION

The Bureau of Vector Control and the mosquito abatement districts represented in the California Mosquito Control Association have for several years recognized the need for biological investigations of California mosquitoes aimed toward evaluating the efficiency of present control methods and developing effective new control methods. About two million dollars each year is expended for mosquito control in this state; thus, control measure refinements may result in extensive savings. The principal mosquito control problems of the state are related to irrigation. Problems of secondary importance are related to natural waters including salt marshes, rivers, lakes, and flood areas. Associated with irrigation mosquito problems, two principal agricultural practices contribute to the main sources of mosquitoes in California's great Central Valley: (1) the irrigation of permanent pasture and (2) the flooding of rice fields.

In view of this urgency, and since investigations of the biology of mosquitoes in rice fields and in irrigated pastures would develop information which could be related to most of the mosquito problems in other agricultural situations, these two problems were selected for initial consideration. A third problem of basic importance is that associated with the development of efficient toxicants, the study of toxicant failures, and the precision application of presently recognized toxicants.

While these problems have been recognized for a number of years, the first large-scale coordinated attack on the problems was developed on a cooperative basis between the Bureau of Vector Control and the California Mosquito Control Association. This was conceived at the 1950 California Mosquito Control Association Annual Conference by a resolution, and through the appointment of a committee designated as the Operational Investigations Committee. The California Mosquito Control Association has, through this Committee, taken positive action in developing and promoting an effective program of biological investigations of mosquitoes in California. Through cooperative agreements between the Bureau of Vector Control and several of the mosquito abatement districts, $25,000 was set aside to conduct these investigations in subvented mosquito abatement districts.

The Operational Investigations Committee [5] in April of 1950, after making an intensive study of the problem, forwarded to the Bureau of Vector Control its recommendations for the investigational program for fiscal year 1951, including nominations of essential local cooperating agencies. Following approval

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by the Executive Committee of the California Mosquito Control Association and the Bureau of Vector Control, three units were established:

1. One unit was established with the Turlock Mosquito Abatement District at Turlock, California, as the administrative entity cooperating with this project.
2. A second unit was established with the Sutter-Yuba Mosquito Abatement District at Yuba City, California.
3. A third unit was established with the Kern Mosquito Abatement District at Bakersfield, California.

All mosquito abatement districts interested in the results of this work have cooperated by furnishing manpower and equipment whenever it was possible for them to do so.

Considerable progress has been made during the brief period of the existence of these three investigational units. The toxicant investigations project has been somewhat delayed, however, due to personnel problems and other reasons.

In discussing the results of these investigations, only the results of the first two will be given; while for toxicant investigations, the plans for the next season will be given.

THE PROGRAM

Investigations of the Biology of Irrigated Pasture Mosquitoes (Conducted at Turlock)

This project has been a cooperative study between the U. S. Public Health Service, the Bureau of Vector Control, and the Turlock Mosquito Abatement District as sponsored by the California Mosquito Control Association.

During the 1950 mosquito season, investigations have been divided into several phases. They have included:

1. A study of the cycles of mosquitoes during the successive irrigations in a permanent irrigated pasture.
2. The study of the feeding habits and activities of adult mosquitoes in a single pasture, and the relationship that these activities may have to the transmission of disease.
3. Flight range and dispersal studies of *Aedes* mosquitoes from irrigated pastures.

In order to facilitate these studies, a field station was established at Turlock, and equipped with materials and personnel. The study area selected was an irrigated pasture located about 8 miles west of Turlock. Temperature and humidity records were kept, using a hygrothermograph. In the course of each of the 18 irrigations in this pasture, a mosquito cycle was begun and completed. During each of these mosquito cycles, records were kept of the hatching and distribution of mosquitoes over the pasture, of the emergence patterns of adults, and of adult density indices.

To accomplish the second phase of the study, females of the species *Aedes nigromaculis* (Ludlow) were taken from the pasture and records made as to whether or not they had fed or were gravid. The engorged females were dissected, and blood from their stomachs was smeared on filter paper. These blood specimens were then stored, and will be tested at a later date to determine which animal hosts provided the blood meal. Diurnal and nocturnal activities of adult mosquitoes were observed, and light trap collections were made both within the pasture and near by.

Two methods were used in the study of flight range. The first called for tagging the mosquitoes with rhodamine-B fluorescent dye, and the second, with a radioisotope P-32. The rhodamine was applied to the mosquitoes in their natural habitat, using an aqueous solution of about one pound to five gallons of water, applied with an insecticide fog generator but omitting the use of the heat mechanism. The radiophosphorus was placed in two large galvanized iron tanks holding about 80 gallons of water in which the mosquito larvae were concentrated. Fourth stage *Anopheles nigromaculis* were introduced into the tanks and there

ingested the isotope. On emergence they contained enough radiophosphorus for easy detection with a Geiger counter (Tracerlab Su-3A Laboratory Monitor).

Investigations of Biology of Rice Field Mosquitoes (Headquarters at Yuba City)

This project has been a cooperative project of the Bureau of Vector Control, and the Sutter-Yuba Mosquito Abatement District, sponsored by the California Mosquito Control Association.

The objective of this study was to increase the knowledge of the natural history of rice field mosquitoes, in view of the need for improving control measures. For the spring of 1950 the principal activities included:

1. A study within a 25-square-mile area, where intensive springtime larvicidal measures had been applied to all infested aquatic sources. The purpose was to determine whether or not this spring control would significantly decrease the numbers of *Anopheles* and *Culex* mosquitoes which occur in the rice fields after they are flooded in May.
2. Studies were conducted to determine the relative mosquito productivity of various aquatic sources, using dipping records as a means of comparison.
3. Inspections of adult resting stations were used to study fluctuations in adult populations.

The study area of 25 square miles is located in southern Sutter County and includes 2,320 acres of rice and 1,960 acres of irrigated pasture. The remaining 11,720 acres are largely fallow fields which are not subject to irrigation. Extensive larviciding was done during the months of March and April in an attempt to control all sources of mosquitoes in this 25-square-mile area. A central, mile-square section was used for intensive observations in the hope that records in this section would indicate the degree of mosquito reduction obtained and would not be influenced too greatly by those areas outside the 25-square-mile, intensively controlled area. Following the flooding of the rice fields in April and May, dipping records were kept on the occurrence of mosquito larvae. Adult resting station and light trap collections were made to determine adult density indices.

To discover additional facts concerning the biology of the principal rice field mosquitoes, *Anopheles freeborni* Aitken and *Culex tarsalis* Coquillett, living specimens were collected and observed under laboratory conditions. The numbers of eggs laid by females of both species were recorded for these conditions. Dissections for ovarian and fat body development of female *Anopheles* in relation to seasonal changes are also under way. Field observations were made of the length of time required for adults to emerge after flooding certain rice field sections. Dipping records indicate that samples taken in one part of the rice field may not represent conditions over the remainder of the field. Therefore, it is exceedingly difficult to establish reliable indices to larval mosquito densities in rice fields.

In the resting station counts for the 1950 season, *Anopheles freeborni* females reached a peak on September 8, 1950.

Observations have been made concerning the swarming and mating habits of *Anopheles freeborni*. It is hoped that this study will demonstrate differences in seasonal activities of both *A. freeborni* and *Culex tarsalis*.

PRESENTATION OF RESULTS

It has been the opinion of the Bureau of Vector Control and the Operational Investigations Committee that three phases exist in the conduct of these studies: first, a study of the natural history of mosquitoes and the effect of toxicants on mosquitoes; second, the organization of results of these studies for presentation in the form of reports to mosquito abatement districts and to the Bureau of Vector Control; and third, interpretation of the information given in these studies so that it can be used effectively in guiding control operations.

From the inception of these projects, every attempt has been made to keep both investigators and mosquito abatement district personnel abreast of all developments related to the organization and operation of the projects, as well as cognizant of the results of the investigations. Thus, knowledge gained can be utilized in the control program of the districts at the earliest possible moment. This has necessitated frequent meetings of the Operational Investigations Committee in which the progress of the studies has been discussed in detail. Coordination of all effort through the Biological Section of the Bureau of Vector Control has worked effectively in directing the purpose of the investigation program. At regional meetings of the Mosquito Control Forums in the San Joaquin Valley, the Sacramento Valley, the San Francisco Bay Region, and in southern California, mosquito control workers have been apprised of the results of each project. Thus, it is the intention of the California Mosquito Control Association and the Bureau of Vector Control to make the most of every dollar spent in this work through rapid integration of investigative results and operational programs.

PLANNING FOR THE FUTURE

In planning future mosquito investigations, there are four phases under consideration for the 1951 mosquito season. These will include:

1. Continuation of flight dispersal studies of irrigated pasture mosquitoes.
2. Investigations directed toward learning more about the eggs of *Aedes, Culex,* and *Anopheles* and the potentialities of methods for destroying mosquito eggs.
3. A continuation of the biological studies of rice field mosquitoes.
4. Expansion and intensification of the study of toxicants for mosquito control.

The first three programs will proceed along much the same lines as during the 1950 season. It is anticipated, however, that in a study of toxicants, we may be able to increase our activities in several ways. The first way is through cooperation with the Corvallis, Oregon, U. S. Department of Agriculture Laboratory. Further, it is hoped that a complete analysis can be made of the resistance displayed by California mosquitoes to toxicants. This project may also undertake to establish the relationships between temperature variations and the action of toxicants on mosquitoes. The toxicant investigations project will employ a professional person to direct a study of the development of new toxicants for mosquito control through field tests of those materials which show promise as a result of laboratory studies. Plans are being made to expand this portion of the program with the assignment of additional personnel through the Bureau of Vector Control, and through wider participation by the mosquito abatement districts in the Central Valley. Thus, in 1951, there is to be an all-out attack on the problem of selecting the right toxicants for mosquito control in California.

DISCUSSION

The approach, both administrative and technical, being used in the study of the biology of mosquitoes important to control programs in California has been presented. It is too early in our work to be able to give much in the way of conclusive data. It is not expected that all of the biological principles learned through this program will have immediate application. All persons engaged in long range mosquito control activities have come to realize that biological investigations have their place in the mosquito control program, and it is with a progressive outlook toward the future of mosquito control in California that these cooperative studies have been established. The results of these studies are not for the benefit of single districts but will have application in the programs of all the districts of this state, and may well provide basic scientific facts useful in the mosquito

abatement programs throughout the country and elsewhere in the world.

CONCLUSIONS

Investigations have been initiated aimed at evaluating present mosquito control methods and developing new methods. This will take the form of a large-scale, all-out attack via the biological approach, the results of which are expected to increase efficiency in California mosquito control procedures.

MOSQUITO CONTROL ON A COMMUNITY-WIDE BASIS

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Health and comfort—at surprisingly economical cost—can be achieved on a community-wide basis through modern mosquito control. Scores of U. S. communities have learned this in recent years. There is increased interest in such control, and in the methods to achieve it.

Prior to the introduction of DDT the main effort of most communities in mosquito control was the application of oil or other larvicide to mosquito breeding ponds in and around the area to be protected, or drainage and filling operations so far as practicable. Such procedure, although resulting in a fair degree of control, at times was largely offset by the adult mosquitoes drifting in on prevailing winds from surrounding untreated areas. That has indeed been the experience at Fargo, where larviciding operations were continued for years, but have of late shifted over almost entirely to the application of DDT for the primary purpose of controlling the adult mosquitoes.

The predominating species of this area are *Aedes vexans* and *A. dorsalis*. They constitute about 75 per cent of the mosquito population. They are noted for their flight dispersal ability and are regarded with particular concern as important vectors of encephalitis. Others of the 31 species recorded by Post and Munro [4] (1949) as of lesser consequence but troublesome at times are *A. sticticus* and *Culex tarsalis*.

Heretofore, DDT has been applied to the residential and park areas of Fargo by means of ground operated sprayers or fog machines. In 1950 a serious invasion of mosquitoes and blackflies, and scattering infestations of cankerworms prompted an application of DDT by airplane because of its speed of coverage as compared with ground operated equipment. Although mosquitoes are controlled by ½ pound of DDT per acre it was decided to make the application sufficiently heavy (1 lb.) to control the other pests mentioned.

The application was made during the period June 13–15. A local aerial spray agency, which used the Stearman type of biplane equipped with a spray boom mounted underneath the lower wing, furnished the materials and made the application. A total of 1,500 acres, comprising the residential area of Fargo and adjoining parks, was covered with the spray at the rate of 1 lb. of actual DDT per acre at a total cost of $3,000.00. This, on the area basis, represented a cost of $2.00 per acre; or, on the basis of the 38,000 population of Fargo, about 8 cents per person.

The blessed anonymity of the research scientist was denied in this spraying

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[4] Post, R. L., and Munro, J. A. Mosquitoes in North Dakota. *Bimonthly Bulletin*, 11 (5): 173–183, 1949.