that there is a heavy concentration of adult *A. freeborni* at the margins of the rice checks and banks of ditches, as contrasted to the interior of the checks and ditches. This finding may have real significance in a control program.

Efforts to control *A. freeborni* breeding in the rice growing areas of California by an intensive early spring larviciding program have not been outstanding. In fact, it can safely be stated that this plan cannot be relied upon to give a satisfactory control.

CONCLUSION

It is not expected that all of the biological principles learned through these studies will have immediate field application. Many will only lead to further research. All persons engaged in long range mosquito control activities have come to realize that biological investigations have a prominent place in the mosquito control program, and it is with a look toward the future of mosquito control in California that these cooperative studies are being continued.

RECENT DEVELOPMENTS IN THE CONTROL OF RICE FIELD MOSQUITOES IN CALIFORNIA

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The rice field mosquito problem in California is actually a combination of three separate problems, all of them expensive and complex for mosquito abatement districts. Control involves three of the principal genera of mosquitoes—*Aedes, Anopheles* and *Culex*—an all-year problem intensified during the warm months of the year when rice fields are under water.

Two of the mosquito species are disease vectors: *Anopheles freeborni* of malaria, and *Culex tarsalis* of encephalitis. But actually we are concerned with more than a vector problem, serious as this is. Mosquito abatement districts in the rice growing sections of California must not only keep the mosquito population below the disease level, but they must reduce mosquitoes to a point that will satisfy the demands of the tax-paying public.

Rice acreage in California amounts to about 300,000 acres, most of it in the warm, dry northern part of the Sacramento Valley. Of this, more than 100,000 acres are outside of mosquito abatement districts. An increase in the mosquito problem has accompanied the increase in rice acreage.

Most rice is sowed by plane on land that is already flooded. Fields are flooded just before sowing, and the first major control problem occurs when they are first flooded. This initial flooding hatches eggs of *Aedes dorsalis* and *A. nigromaculis* which have been laid a year or more before. In late May and early June, *Culex tarsalis* larvae appear in quantity around the outside borders of fields and even within some fields. *Culex* adults are numerous by the middle and end of June and continue into the fall. The anophelines reach the adult peak in August and September with all aquatic stages of *Anopheles freeborni* in rice fields at this time. From late June until they are drained rice fields become generally infested by larvae of *Culex* and *Anopheles.*

Fortunately, the *Aedes* problem has been a matter of controlling only the one generation early in the spring. Although only one *Aedes* generation appears in any one field, the problem is complicated because *Aedes* larvae may appear in hundreds of acres of rice flooding at the same time and all requiring immediate control. In the past, control has been tedious, costly, and not always effective. Men with back pumps walked the winding levees and sprayed all the water they could reach. This method took so much time that only a small acreage could be covered, and many fields had to be neglected.

Another disadvantage became apparent in the slow flooding fields that might require several treatments before they were completely flooded—adults were emerging at the high end while the low end was not yet flooded. Another method that has been tried, and is still useful on a small scale at least, is the dispenser method of injecting a concentrated emulsifiable insecticide at the pump or main head gate or even at each irrigation box. This method distributes the insecticide through the field satisfactorily but is expensive.

As a quicker, more effective and cheaper means of control, the Sutter-Yuba district several years ago devised the method of adding 50 per cent DDT wettable powder to each plane load of rice seed. The powder sticks to the rice seed and settles with it into the water. The dosage effective against *Aedes* larvae was determined as one-quarter to one-half pound DDT per acre or one-half to one pound of powder. This amounts to only three to six extra pounds to each plane load of rice, as a plane generally sows about 6 acres a load. Drilled and slow flooding fields must still be treated in other ways.

A variation of this method has been worked out by the Butte County district which has determined that 3 lbs. of powder per acre will kill the tadpole shrimp, a crustacean pest, which causes serious damage during the early stages of rice development. By adding the extra poundage of powder, growers can control the shrimp at the same time as a district controls *Aedes* mosquitoes.

The *Culex* and the *Anopheles* control problems are not approached in quite so clear-cut a fashion as the *Aedes* problem. In some ways the two can be considered together and in other respects they are entirely distinct. Both mosquitoes are vector mosquitoes and therefore a public health problem. The larvae of both species can be found together or in similar places and both species infest rice fields. *Culex tarsalis*, however, is a summer pest while *Anopheles freeborni* is principally bothersome in the fall and late winter.

The *Culex* problem is so widespread that we have had to consider adults a necessary evil and use aerosol equipment almost continually. The first *Culex* larvae in any numbers appear in late May in seepage around the outside of fields. Small ditches near the fields often fill up as the water level in a nearby field is raised. Another *Culex* breeding place is the borrow pits left after border levees are raised. The lack of a complete, clean drain also causes *Culex* trouble. Water with no other place to go spreads around the outside of a field. *Culex* trouble can also develop in fields themselves as early as the first flooding. This is true of fields overgrown with weeds and tules, fields that have low swampy spots, those with grass-covered old levees, and fields with no definite border levee to prevent water from drifting into adjoining weed patches.

Sacramento Valley districts concentrate much of their control work upon seepage areas. Men equipped with back pumps spray the seepage around the outside of fields. Pressure spray rigs on jeeps are also used when possible. However, many places are nearly inaccessible even on foot and a vast amount of territory must be covered in a short time.

To reach the inaccessible but still important larval sources and cover the territory quickly, a dusting airplane has been tried experimentally with some success. The plane applies a very light dosage of DDT wettable powder around the edges of the fields. Weather conditions must be nearly windless for dusting and the plane must often fly high because of obstructions. Dust is preferred to an oil spray which could conceivably cause damage to tender rice shoots lying on the water surface at this time. However, beneficial control work outside a field can be virtually nullified by weed infested fields.

Anopheles freeborni larvae are often found with *Culex tarsalis* larvae but adults are not very noticeable until August and September. Adult females hibernate in various man-made shelters such as buildings, culverts and bridges, and also in natural shelters. The adult females become active with the first warm days in January and February as the temperature rises to about 60° F. or above. Larvae have been found in almost every month of the year but the first instar larvae of the spring brood appear about the end of February or the first of March in rain water ditches and pools. As with the *Culex* problem, fields with weeds and tules usually become infested with anopheline larvae as soon as they are flooded for sowing.

In 1946 the Sutter-Yuba district came into existence and was the first large district (430 square miles) to begin operations in the concentrated rice growing section of the Sacramento Valley. The district's method of dealing with the anopheline rice field problem was patterned after that of the TVA which used a plane equipped with a thermal exhaust aerosol generator. Each load covered more than 400 acres with an aerosol spray which was highly effective against anopheline larvae. Every fall for four years, 20,000 to 30,000 acres of rice were treated in this way.

Although the method was spectacular and economical on a cost per acre basis, it did not serve the purpose; a heavy population of anopheline larvae reappeared within a few days after an apparent 100 per cent control job. Because of the acreage involved, it was too costly to repeat every week or two and the method was abandoned. Adults of both *Culex tarsalis* and *Anopheles freeborni* protected by weeds on the levees and *Culex* larvae were virtually unaffected by the aerosol spray.

A plane with a spray boom is still useful in anopheline control, particularly in the spring, upon long sloughs, shallow lakes, and receding floodwater lakes and lagoons. Butte County uses a plane in the fall to apply a liquid spray at one quart to an acre. It reports good results on its rice fields.

In the last two or three years, some of the districts have been paying more attention to larvae-producing residual water near rice fields. They have taken advantage of the fact that a great deal of beneficial larviciding can be accomplished before rice fields are even flooded—a recommendation first advanced some thirty years ago by Dr. S. B. Freeborn of the University of California.

Such large areas as river bottom lakes, lagoons, and borrow pits may require the use of a plane. Heavy populations of anopheline larvae have been found after floodwaters recede, and although the spring treatment method, which has been adopted by the Sacramento-Yolo and the Sutter-Yuba districts, considerably reduces the population of mosquitoes that infiltrate into rice fields, other conflicting factors must also be considered.

For instance, rice fields are apparently first invaded from some nearby source that may be a mere few feet to a hundred or so feet from a field. Early in the year, near almost any prospective rice field, there exists some tule patch or ditch of shallow water where *Anopheles* larvae can be found. Larviciding or eliminating such a source would seem logical as a control measure for any particular field. But *A. freeborni* is considered to be a long-range flier and thus could invade fields over a wide area and offset this work. However, this is a possibility in control that must be considered and investigated more thoroughly.

Although, from the information given, it is obvious that it is difficult to recommend positive specific control measures, there are certain practices that we believe will greatly reduce the extent of the *Culex* and *Anopheles* problem in and around each rice field. These are as follows:

1. An adequately cleaned and graded drain or drains leading from the field to a free-flowing main drain. The field drains also should be accessible to mosquito control equipment if necessary.

2. Clean and complete cultivation of

each field each spring so that there will be no weed growth within the field at the time of flooding and sowing.

3. New levees each spring clean of weeds at sowing time; resurveying should not be necessary after the first year.

4. A definite border levee to prevent water from spreading into weed patches along the outside edges of a field.

5. A border levee higher than field levees to avoid seepage and loss of water from the field.

6. A graded field without low spots that favor weeds and inhibit rice growth.

7. No unnecessary or unused ditches or borrow pits to hold water near the field—most of these places can be easily filled.

Other possibilities exist such as building the border levee from inside a field to eliminate a ditch or borrow pit on the outside that often fills up with water. The shape of the levees themselves might encourage weed growth so that sharp-sided levees might be preferable.

So far as rice field control problems are concerned, the trend in our thinking is away from complete dependency upon the post-war magic insecticides. We believe we must examine other ways, particularly corrective cultural practices, as a possible solution. Some of the ideas we now have are not necessarily new and many were advanced a long time ago. But they are still sound. More thorough studies of the ecology of rice field mosquitoes can contribute materially to the efficiency of control.

PSOROPHORA CYANESCENS (COQUILLETT) NEW TO THE MOSQUITO FAUNA OF NEW MEXICO [1]

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Items of interest to students of mosquitoes of western United States have been disclosed in light trap data compiled in this office for the use of the Mosquito Control and Allied Problems Work Group of the currently active Arkansas-White-Red River Basins Inter-Agency Committee. The sub-committee on problems relating arthropods to public health in AWR Basins water resources projects has, as one of its functions, the task of gathering mosquito distribution and seasonal density data from areas not previously adequately sampled. Adults of *Psorophora cyanescens* (Coquillett), a vicious biting, temporary pool breeder, common to South Central States, are now reported from Tucumcari, New Mexico (August, 1952). *Culiseta inornata* (Williston), normally considered to be an early spring and late fall mosquito, has been taken in small numbers during each of the summer months (June, July, August and September, 1952) from the Northeast New Mexico-Southeast Colorado area of AWR Basins.

[1] From the Communicable Disease Center, Public Health Service, Federal Security Agency, Atlanta, Georgia.