

THE RICE FIELDS AS A FACTOR IN THE CONTROL OF MALARIA

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The introduction of rice culture into the Sacramento and San Joaquin Valleys of California has called forth much comment as to its possible influence upon the increase and control of malaria which is already endemic in both valleys. Rice was first grown commercially in California in 1912 when 1,400 acres were planted at Biggs in the Sacramento Valley. The acreage has increased at the rate of over 100 per cent a year since that time until 1916 saw about 75,000 acres under cultivation. The industry is an exceedingly fortunate one owing to the fact that land rendered useless by previous cropping or unfit for other crops on account of faulty texture has been used for rice, thus adding materially to the state in wealth.

The cultivation of rice demands that the entire acreage be flooded to the depth of four or five inches with water stagnant or in a gentle current for a period varying from 145 to 160 days beginning about June first.

Theoretically, at least, these large bodies of standing water, well areated by a gradual addition of water and the presence of the growing rice, should form ideal breeding places for malaria-bearing mosquitoes. However, there is a deep grounded belief among those who deny the ability of the rice fields to produce mosquitoes, that there is an "essential something" in the rice fields that prevents mosquito breeding. This "essential something" is explained by another mystery,—the ecological factors governing the habitat of the different species of mosquitoes. Just as salmon, brook-trout, and steel-heads choose different breeding grounds, so the different species of anophelines invariably deposit their eggs in locations where a given set of determining factors are present. Some, it is true, have a wide range of selection but the majority are limited to very definite locations. For example, *A. malefactor*, a tropical anopheline, breeds almost exclusively in hollow tree trunks while *A. ludlowii* is limited to brackish or salt tide water. Again *A. febrifer*, a Philippine malaria carrier finds its ideal habitat at the edge of running streams and is seldom present in stagnant pools as is the case with our domestic anophelines. The statement that California rice fields will not furnish breeding grounds for malaria-bearing mosquitoes is based solely on the empirical application of the knowledge that in certain parts of the world, the hypersusceptible anophelines of the district do not find their natural breeding places in the rice fields.

Barber has shown that the rice areas of the Philippines are singularly free from malaria due to the fact that the typical rice field anopheline, *A. rossi*, is only a weak and somewhat doubtful carrier of malaria while the intensive carrier, *A. febrifer*, is a stream breeder whose breeding places are destroyed with the introduction of rice paddies. He follows these remarks with the statement that " . . . in some parts of the Philippines the further development of rice culture may result in the diminution of malaria."

Watson, writing of malaria conditions in the Federated Malay States, comments on the absence of malaria in the rice districts and its abundance in the hill country and suggests rice culture as an anti-malarial measure.

Kendrick, working in central India, observed that the rice districts on the broad open plains were practically free from malaria but that when shade such as that afforded at the edge of the jungles was present the species of anopheles changed and malaria was present. In all of these instances of malaria free rice districts, the anophelines present lacked the ability to transmit malaria or were relatively weak carriers.

From these findings of men who have dealt with the problem in various countries and under different conditions, the only safe deduction that can be made is the fact that each district requires separate investigation regardless of apparent similarity. The Californian problem can not be settled by Indian or Philippine investigations or even by those under way in our own southern states.

In order to determine, therefore, the relative importance of the rice field mosquitoes as a factor in malaria control, it is necessary to ascertain (1) what anophelines breed in the rice fields and the pools adjacent to and caused by them, (2) their susceptibility as malaria carriers, and (3) their relative abundance.

In the Sacramento Valley rice fields two anophelines find reasonably satisfactory breeding grounds judging from the number of larvæ taken. *Anopheles occidentalis* D. & K. and *Anopheles pseudopunctipennis* Theob. are both present in large numbers, making up about one half the mosquito population of the district. Probably 70 to 80 per cent of these two species find their breeding places in the pools attendant to the rice fields and caused by seepage, overflow and faulty water regulation. The other 20 to 30 per cent breed in the rice fields proper in the shallow water near the contour checks.

A. occidentalis is a recently named species which was previously considered to be *A. quadrimaculatus*, the principal eastern and southern malaria-carrier. Nearly a thousand specimens of *A. occidentalis* in our collection show all stages of resemblance to *A. quadrimaculatus* from those fairly well defined to those that are practically identical

with the latter. No experimental work has been done to show that *A. occidentalis* is susceptible to the parasite of malaria but since it is one of only two anophelines that are found in highly malarial districts and the other,—*A. pseudopunctipennis*, is only slightly susceptible, it seems reasonable to believe that it is the chief carrier. To this circumstantial evidence might be added the additional reminder of its close connection and perhaps synonymy with *A. quadrimaculatus*, a proven carrier of malaria in many parts of the United States.

Beyer and his associates stated that *A. quadrimaculatus* could be infected with the tertian and quartan types of malaria but not with estivo-autumnal. However, Lushberg succeeded in infecting eight out of 48 specimens of *A. quadrimaculatus* that were allowed to feed on a volunteer suffering with the estivo-autumnal fever. Von Ezdorf, in a later paper, states conclusively that *A. quadrimaculatus* is susceptible to all three types of malaria.

A. pseudopunctipennis has always been looked upon doubtfully as a malaria carrier. Darling succeeded in infecting four out of 27 of this species with estivo-autumnal parasites, but a very small series of experiments with the parasites of the tertian and the quartan types of fever proved negative.

The apparent contradictions of the different findings regarding the infectivity of the same species of mosquito, is by no means limited to those above stated. The same type of contradictions is prevalent throughout the literature of infectivity experiments. This may be due in some cases to faulty technique, confused nomenclature, or the failure to state what type of malaria parasites were used for the experiment, for different types of malaria are carried by different species of *Anopheles*. Many times mosquitoes have been listed as non-malaria carriers on the basis of experiments with one type of malaria although they were the most important carrier of another type. Mitzmain has proved this in showing that *A. punctipennis* is a strong carrier of tertian fever but absolutely negative to estivo-autumnal. Another source of error seems to be in the failure to consider ecological factors. Some species seem capable of carrying malaria in one district while repeated attempts to infect them in other portions of the country with the same type of malaria invariably result negatively. Majoribanks states that *A. listoni* is the chief carrier in parts of Bengal and although occurring in large numbers in western India has never been found infected despite the fact that malaria is endemic there.

Considering both the circumstantial and experimental aspects of the California problem, I feel that we can safely say that in the rice districts *A. occidentalis* is the important carrier with perhaps a few scattered infections due to the agency of *A. pseudopunctipennis*.

These two mosquitoes breed in the rice fields close to the contour checks which wind about through the fields to hold the water at the different levels, their abundance depending largely on the character of the rice stand. A heavy and uniform stand of rice, growing well up to the checks, produces relatively few mosquitoes while a sparse stand with irregular growth at the checks generally breeds anophelines in large numbers. Far more important than the rice fields proper, however, are the overflow pools of surplus water. These vary in size from small ~~wayside~~ ^{wayside} vast water-soaked sloughs that lack the natural drain. ~~When the water is~~ ^{When the water is} ~~dry~~ ^{dry}. These bodies of water, both large and small, breed enormous numbers of mosquitoes and are entirely unnecessary. Careful construction of the irrigation ditches together with an intelligent and economical use of water would entirely eliminate them in a majority of cases.

The irrigation of the rice fields does not begin until May. The mosquitoes, however, begin active breeding in March and April, utilizing neglected pools of standing water. Again after the water is drawn from the rice fields in October, the mosquitoes continue to breed actively until the latter part of November, again utilizing neglected and useless pools. If, therefore, all possible breeding pools could be controlled before and after the rice season as well as the outside pools that occur as results of rice cultivation during the season, the mosquito population would be so considerably reduced that the number breeding in the rice fields proper would be almost negligible.

The best agricultural methods demand that the land used for rice and the adjacent territory be as nearly dry as possible before the crop is planted. Again the irrigating water should be on the fields only just long enough to mature the crop. As the rice approaches maturity every detail should be undertaken to ensure immediate drainage away from the fields at the moment that the crop matures. The fields should then remain dry until they are naturally irrigated by the winter rains. Thus it will be seen that optimum agricultural methods coincide with optimum mosquito control measures and when the industry has become scientifically standardized the mosquito question will be controlled automatically to a large extent.

Unfortunately, a large percentage of the rice cultivation is carried on by tenant farmers whose only vision is to reap the speediest and most lucrative returns. The result has been as might be expected, the irrigation ditches are badly maintained, the land is robbed of its chemical constituents by poor agricultural methods and the profligate use of water. Perhaps the most striking phase is the living conditions of the workmen. The labor is transient and many of the shelters are mere shacks lacking any attempt to exclude mosquitoes with the result

that infected laborers rapidly spread their infection throughout the district by means of the numerous mosquitoes.

The control of those mosquitoes that breed in the rice fields proper is an extremely difficult matter. Larvicides that are efficient in mosquito control, such as oil, salt, etc., are detrimental to the rice. Fish are not successful owing to the difficulty in keeping the fields stocked and their inability to feed in the shallow water inhabited by the mosquitoes. Dragonflies as adults may be looked upon as a check but not as a control. The dragonfly larvæ, even in the presence of an abundant supply of mosquito larvæ and pupæ, prefer cannibalism.

Theoretically, malaria can be controlled in two ways. If everyone in a malarial district could be cured by means of quinine treatment the mosquitoes would have no point at which to become infected or if everyone would take a daily prophylactic dose of quinine, the chances of infection even though bitten by an infected mosquito would be materially lessened and the death of the last infected mosquito would see the community free from malaria. Secondly, if all malaria-bearing mosquitoes were eliminated there would remain no transmitting agency to convey the disease from the sick to the well and again malaria would disappear from the community with the recovery of the cases infected at the time of the elimination.

Experience in different lines of preventive medicine points out the difficulty of administration of universal quinine treatment. In this country of personal liberty it would be practically impossible to force any such measure upon the people no matter how beneficial it might eventually be. On the other hand, those who have had experience with anti-mosquito campaigns know the difficulties attendant to nominal *control*, to say nothing of the *elimination* of mosquitoes from any given district.

The logical control of malaria in the rice districts of California rests in the careful application of a combination of these two methods,—zealous anti-mosquito campaigns together with careful quinine treatment or prophylaxis.

1. The rice field becomes an economic factor in the control of malaria in endemic localities when they offer breeding grounds to large numbers of anopheline mosquitoes that are capable of transmitting the malaria parasites. This is true in the California rice fields.

2. The pools of standing water outside the rice fields proper, but owing their existence to faulty agricultural methods of the rice growers, are far more important than the rice fields proper.

3. The control of breeding places outside the rice fields before, after and during the rice season combined with an application of those methods of rice cultivation that are recognized as agriculturally sound would substantially control the mosquitoes.

4. Larvicides or predaceous animals are of little use in the rice-fields.
5. Organized quinine prophylaxis and treatment together with anti-mosquito precautions would decrease materially the incidence of malaria.

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CHAIRMAN A. W. MORRILL: It will probably be best to wait and discuss this paper along with the next one which is to be read by Prof. W. B. Herms.

A STATE-WIDE MALARIA-MOSQUITO SURVEY OF CALIFORNIA

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The great state of California, bathed for many miles by the waters of the Pacific Ocean, favored by a semi-tropical climate, well deserves to be called the nation's health resort and playground, but while Burbank has shown how the spine-covered cactus may be made smooth to the touch, and we now have under cultivation many acres of spineless cactus, there still thrives in many parts of the state the festive mosquito, not yet shorn of its beak nor devoid of its ability to transmit malaria. Evidenced by letters in my possession there are some per-