# Who should pay for rice-field mosquito control?

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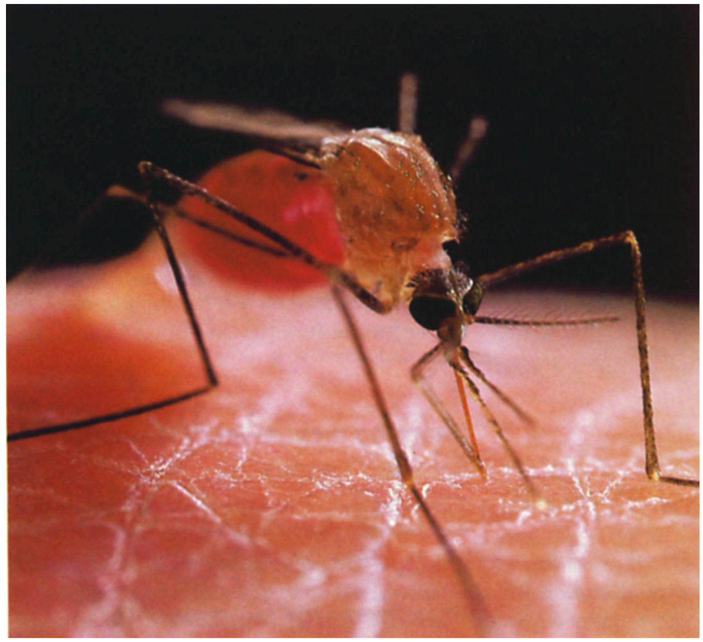
***Jurisdictional limits may prevent local agencies from achieving adequate control***



**The "rice-field mosquito," *Anopheles freeborni*.**

**Sampling for mosquito larvae.**

Rice-field mosquitoes pose a particularly knotty problem for public health officials in California. Rice, a profitable crop, is especially valuable because it grows well on relatively poor land. Yet the paddy cultivation methods widely used in California create a habitat that has potential for breeding large numbers of mosquitoes.

Two mosquito species that breed in large numbers in rice fields are of particular interest: *Culex tarsalis*, the vector of encephalitis, and *Anopheles freeborni* (the "rice-field mosquito"), the vector of malaria. Mosquito control is the principal means of preventing the outbreak of these diseases. The seriousness of these illnesses makes mosquito control an important public health concern, especially given the possibility that such diseases could attain epidemic proportions should control efforts break down.

Mosquito control is the responsibility of tax-revenue-supported public agencies, mosquito abatement districts (MADs), which are organized and maintained under terms set forth in the California Health and Safety Code. In the Central Valley, especially in the Sacramento Valley, rice-field mosquito control is a large part of the MADs' responsibilities for six months (March through September) of the year. Attaining satisfactory levels of mosquito control presents problems of technology, finance, and organization for all districts with significant amounts of rice acreage in or near them.

Economic considerations are a central component of the problems these MADs face. Here we report our analysis of the situation, focusing on three types of economic considerations. First, we compare the costs of different methods that achieve MAD target control levels. Second, we compare different levels of intensity and spatial coverage of control targeted by MADs to evaluate the desirability of the different levels and hence of alternative MAD operating methods. Finally, we address the question of equity in MAD finance and organization raised by the role of rice growers and discuss their implications for MAD revenue-raising methods and jurisdictional limits.

## The cost of control

There are two fundamental approaches to mosquito control: targeting the larval stage as the principal means of reducing populations as a whole, and targeting adult mosquito populations alone. In practice, larval control generally keeps mosquito population levels much lower than does adult control. The choice between these two strategies therefore depends mainly on the overall level of control found to be desirable.

Larval control can be implemented by a variety of methods, among which three types have traditionally been used: chemical treatments, mechanical means (mainly source reduction), and biological controls.

Sole reliance on chemical treatments has important drawbacks. The treatments often lead to secondary mosquito resurgence: in many cases, mosquito populations reestablish themselves more rapidly than do their invertebrate predators (which are also affected by the broad-spectrum insecticides in general use). As a result, chemical treatments may intensify mosquito problems. In the short run, this problem can be handled with additional treatments.

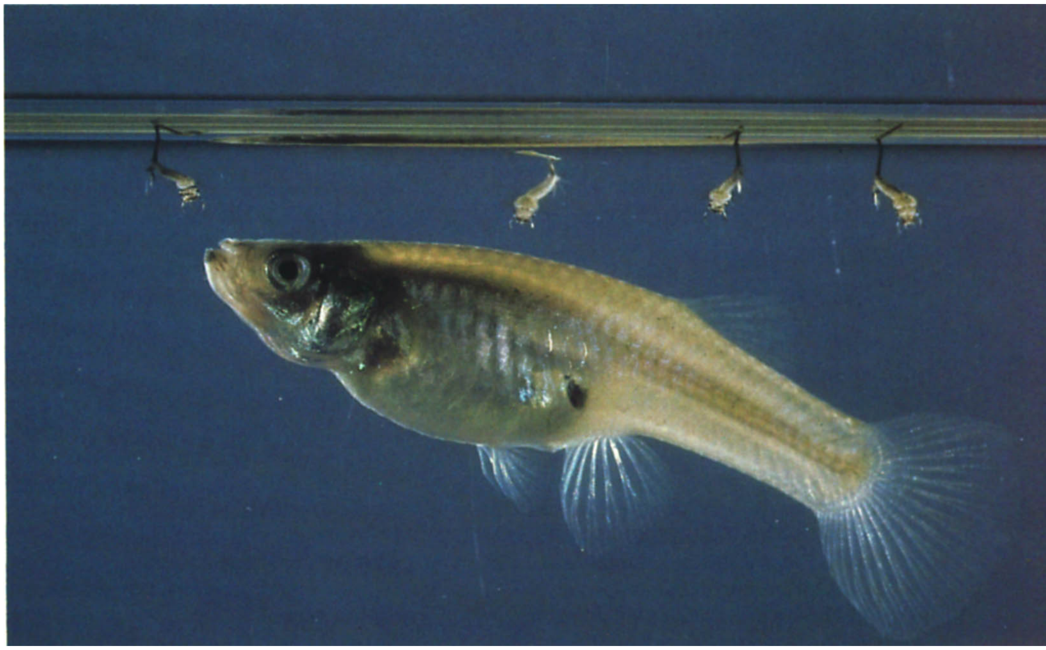
A more significant drawback is the inevitable spread of resistance in mosquito populations, which reduces the effectiveness of the insecticides in use. The short-run solutions are to use larger quantities of particular insecticides or switch to new ones. Since the most cost-effective insecticides are usually the ones in use, the growth of resistance increases cost in the short run.

In the long run, though, resistance tends to render broad classes of insecticides unusable. From a public health point of view, the phenomenon raises the specter of a breakdown in control over mosquito populations: a time could come when MADs simply do not have effective chemicals to use.

The main alternative to chemicals (and, in fact, the prevalent method of mosquito control before the advent of chemical methods) is source reduction — removing the habitats in which mosquitoes breed and grow. Source reduction methods have been quite cost-effective in a number of contexts — in the Central Valley, most notably in the drainage of irrigated pastures. Unfortunately, source reduction methods cannot be applied to California rice fields: dryland (non-paddy) cultivation produces yields about half those obtained under paddy cultivation, at about the same cost.

The main alternative method for larval control in rice fields is thus integrated control, combining the use of biological control agents with chemical treatments. The principal biological agent in use has been the mosquitofish, *Gambusia affinis*.

To compare the alternatives for rice fields, we performed a regression analysis of annual data obtained mainly from the Fresno-Westside MAD (FWMAD) for 1969-82 on rice acreage sprayed, planted, and stocked with mosquitofish, time spent on inspection during the rice season, and time spent distributing mosquitofish. We assessed the effectiveness of this integrated strategy relative to pure chemical control in two areas: the average number of chemical treatments per acre required to meet FWMAD control targets and the hours per person per acre required for rice-field inspection. Our findings have three important implications.



**The mosquitofish, *Gambusia affinis*, is a major biological control agent in rice fields.**

□ The use of mosquitofish cuts larval control costs. An integrated larval control strategy dramatically reduces the average number of pesticide treatments and inspection time required: when 100 percent of the rice acreage is stocked with mosquitofish, treaments fall by 90 percent and inspection time by 65 percent (table 1). As a result, the cost per acre of attaining the district's control targets falls by over 60 percent.

□ A major obstacle is the lack of reliable supplies of sufficient numbers of mosquitofish. Although widespread adoption of integrated control can substantially reduce larval control costs, many MADs, especially those in the Sacramento Valley, simply cannot get enough fish to stock more than a small fraction of the rice acreage within their borders. Our analysis suggests that research and development efforts focused on methods of mass-rearing and distributing mosquitofish could play a critical role in helping to overcome this constraint.

□ We also examined the potential usefulness of narrow-spectrum insecticides against rice-field mosquitoes, in particular, Bti (*Bacillus thuringiensis* var. *israelensis*), a bacterial toxin that has received considerable research attention. Our analysis suggests that, at current price levels, the use of Bti would have to halve the average number of treatments required per acre before be-

**TABLE 1. Effects of mosquitofish use in rice fields on Fresno-Westside MAD operations**

| Percentage of fields stocked | Annual avg. no. treatments/acre | Annual inspection time/acre | Annual costs/acre |
|---|---|---|---|
| % | | *hours* | *$* |
| 0 | 3.9 | 0.23 | 11.70 |
| 25 | 2.2 | 0.18 | 9.60 |
| 50 | 1.3 | 0.14 | 7.50 |
| 75 | 0.7 | 0.11 | 5.30 |
| 100 | 0.4 | 0.08 | 4.30 |

**Source:** Based on regression analyses of 14 years of data obtained from FWMAD and the Fresno County Agriculture Commissioner's Annual Reports.

**TABLE 2. Costs and benefits of alternative mosquito control strategies as related to risks of contracting encephalitis**

| Increasing levels of control | Risk (per 100,000 people)* | Incremental reduction in risk per 100,000 people | Incremental value of reduction in risk (per person)† at mortality of: 15% | 5% | Incremental cost of control (per acre of rice)‡ | Minimum human population density at which incremental benefits exceed incremental costs (per acre of rice) at mortality of: 15% | 5% |
|---|---|---|---|---|---|---|---|
| No control | 4.43 | — | — | — | — | — | — |
| Adult control (Sutter-Yuba MAD) | 2.12 | 2.31 | $2.45 | $1.30 | $0.16 | 0.07 | 0.12 |
| Integrated larval control (Fresno-Westside MAD) | 0.47 | 1.65 | $1.75 | $0.93 | $4.14 | 2.37 | 4.45 |

*Correlation between mosquito population and encephalitis risk for the Central Valley as a whole derived from J.G. Olson, *The Impact of Culex tarsalis Population Density and Physical Environmental Factors upon Mosquito-Borne Encephalitis in Humans and Equines in California.* Unpublished Ph.D. dissertation, Univ. of Calif., Berkeley, 1976. Mosquito populations associated with alternative control levels obtained from mosquito count data for the Sutter-Yuba and Fresno-Westside MADs provided by M.M. Milby, Univ. of Calif., Berkeley.

†Morbidity costs obtained by updating to 1983 price levels the estimates of P.M. Schwab, "Economic Cost of St. Louis Encephalitis Epidemic in Dallas, Texas, 1966" *Public Health Report* No. 83, Oct. 1968. Mortality costs obtained by updating to 1983 price levels the average value of life estimated by G. Blomquist, "The Value of Life-Saving: Implications of a Consumption Activity", *Journal of Political Economy* vol. 87, no. 3, June 1979.

‡Costs of adult control estimated from data for 1981 provided by E. Kaufman, manager, Sutter-Yuba MAD.

coming cost-competitive with the broad-spectrum insecticide parathion.

## Control targets

Our second major question was whether or not the control levels targeted by MADs meet the levels that the public demands. Mosquito control benefits the public at large; it is "consumed" collectively by all members of the public living within the boundaries of a given MAD and is paid for collectively from property tax revenues. In other words, people pay for mosquito control indirectly and pay according to the assessed value of the real property they own, not according to the level of control they want for their own environment. As a result, one cannot measure demand for mosquito control by examining amounts purchased by individuals. In cases involving public goods, one typically measures demand indirectly by estimating individuals' willingness to pay for the benefits they derive from the goods in question.

Potential benefits of rice-field mosquito control in California are reductions in the incidence of encephalitis and malaria and in the nuisance caused by mosquitoes. We restricted our attention to the reduction of the risk of encephalitis morbidity and mortality and ignored the other benefits. Furthermore, we conducted our analysis in a risk-neutral framework: we ignored any value the public might place on the reduction of uncertainty about the risk of contracting encephalitis (as opposed to the value of having reduced the risk of catching the disease).

These considerations imply that we underestimated benefits significantly. Since we tended to overestimate control costs (for example, by using contract prices instead of actual costs), we felt that our comparison of costs and benefits would give a suitably conservative estimate of the desirability of different mosquito control targets.

We estimated the average willingness to pay for reductions in encephalitis risk as the average savings realized from reductions in the incidence of the disease. These savings have two components: a morbidity cost (medical costs incurred plus the value of work and leisure lost should one contract the disease) and a mortality cost (the value of life lost should one die from the disease). Mortality rates have ranged from around 5 percent in California to 15 percent in Texas. Since mortality rates in future epidemics in California are uncertain, the values in table 2 represent an analysis at both levels.

We compared the costs and benefits of encephalitis risk reductions for two levels of mosquito control: that achieved by an adult-control strategy in the Sutter-Yuba MAD and the higher level achieved by integrated larval control in the Fresno-Westside MAD. The results of these comparisons are expressed in a figure reflecting the smallest number of people per acre of rice within a 10-mile radius of a rice field (since the flight range of *Culex tarsalis* is 5 to 10 miles) for which incremental benefits exceed incremental costs. As long as incremental benefits exceed incremental costs, the higher level of control is desirable.

The human population densities required for either level of mosquito control to be desirable are quite small (table 2). One can conclude that almost every community in the Central Valley within 10 miles of a rice-growing area should at least conduct adult mosquito control measures, whereas larger communities should adopt larval control. Since these figures overestimate the actual population densities required, greater levels of control are probably even more desirable than they appear here.

The evidence suggests that MADs in the San Joaquin Valley are attaining desirable levels of mosquito control; most have adopted integrated larval control. But levels of control in the Sacramento Valley appear to be less than desirable.

There seem to be three main reasons for the failure of Sacramento Valley MADs to achieve adequate levels of mosquito control:

- MAD managers may want to adopt integrated larval control for rice fields within reasonable distances of population centers but may be unable to afford such measures. In the Sutter-Yuba MAD, for instance, integrated larval control would have cost $608,450 for the 141,500 acres of rice planted in 1981, while the district's entire budget for the year amounted to only $655,165.
- Many Sacramento Valley MADs cannot increase control levels by using biological control on significant proportions of the rice acreage, because mosquitofish supplies are inadequate.
- The territory of some MADs includes only the population centers and few or none of the rice fields that are the main sources of mosquitoes. R.K. Washino, Professor of Entomology at UC Davis, has pointed out that the Colusa MAD has within its boundaries only 22.5 percent of the 126,300 acres of rice in that county; Glenn, less than 10 percent of 75,000 acres of rice; and Placer, none of 8,000 acres of rice. In such cases, jurisdictional limits, as well as the financial restrictions they impose, prevent MADs from achieving adequate levels of mosquito control.

## Equity

Our third question concerned equity in MAD finance and organization, specifically the role of rice growers.

Rice-field mosquitoes are an external diseconomy of rice production: they are a product of paddy rice cultivation, which the public receives, willing or not, and for which the public is not compensated. The key question with respect to equity is that of property rights: does the public own absolutely the right to an environment devoid of mosquitoes produced by rice fields? Do growers own absolutely the right to produce mosquitoes at will? Should these rights be split in some proportion between these two groups?

California law is ambiguous on this point. Current practice in essence recognizes a right of rice growers to produce mosquitoes unimpeded, as shown by two facts. The first is that growers pay for mosquito control only as members of the general public — that is, through their property taxes in accordance with the assessed value of their rice fields. They do not pay an extra charge based on the fact that their fields tend to produce a significant proportion of the total mosquito population. The second is that in several cases in the Sacramento Valley, rice acreage surrounding towns is excluded from the boundaries of organized MADs. The implication is that the mosquitoes produced in the rice fields are a problem for those living in the towns only and are not a concern of the rice growers.

This *de facto* assignment of rights is not necessarily the one that would emerge from an explicit social choice. An alternative would be to grant some proportion of those rights to the public at large and thus to impose some additional responsibility on rice growers to pay for mosquito control. Such a change could be made (1) by means of a tax on rice acreage planted to raise revenue for MAD operations and (2) by the expansion of MAD boundaries to include all rice acreage within 10 miles of population centers. Together, these measures would give MADs in the Sacramento Valley the financial and organizational resources to achieve the levels of mosquito control that our analysis suggests are socially desirable.

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