INTEGRATED PEST MANAGEMENT: OTHER PESTS

Integrated pest management research: mosquito control

Russell E. Fontaine   Charles H. Schaefer

The concept of integrated pest management in California mosquito control was visualized and put into practice from the beginning of the first mosquito control program in California in 1904. University of California scientists, working with community sponsors of antimalaria projects in California, evaluated and advocated chemical control (spraying breeding areas with petroleum oils), physical control (eliminating breeding areas), and biological control (using the fish mosquito predator, *Gambusia* sp.) as a three-pronged attack against the mosquito.

The blending of these three operational components in the early period of California mosquito control evolved naturally—mosquito problems were themselves a product of complex causes.

Reliance on chemical control replaced the integrated program when DDT was introduced during World War II. DDT and its related compounds gave spectacular results against virtually every kind of mosquito and mosquito-borne disease. Other methods were overshadowed by the quick and easy solutions offered by DDT.

Although dramatic progress was made in mosquito control and in the suppression of mosquito-borne diseases under chemical control, the gains were impossible to sustain because of fundamental defects in the method. The most critical was the appearance of mosquito resistance to insecticides—a worldwide phenomenon. Resistance evolved because of the need for repetitive applications to suppress rapid resurgence of treated populations, aggravated by the lethal action of insecticides on mosquito predators and other natural mosquito enemies. As more insecticide was applied, more was needed until the level of resistance precluded effective control. Costs escalated, hazards of environmental contamination increased, and severe restrictions on insecticide use were imposed. Ironically, excessive reliance on insecticides had created problems as complex as those that originally prompted the shift to chemical control.

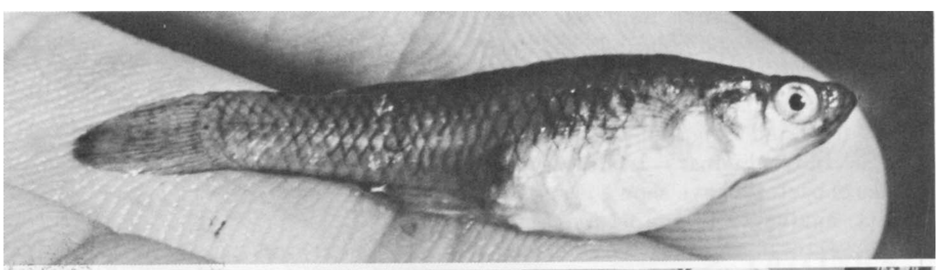
Crisis in mosquito control

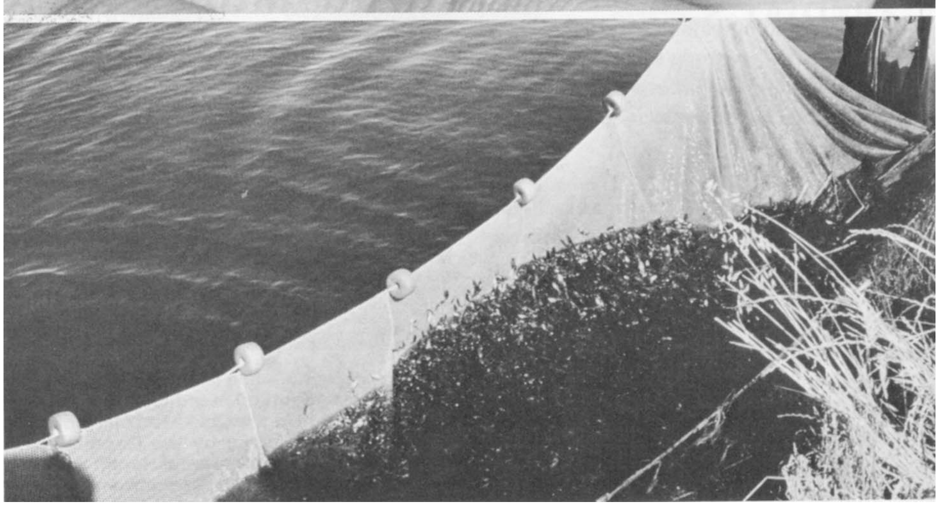
The post-World War II difficulties reached a critical stage in the late 1960s when mosquito control was threatened by deterioration and resurgence of mosquito-borne diseases already occurring in the malaria and other vector disease programs overseas.

In search of a solution, most of the mosquito control agencies in California supported accelerated mosquito research by the University of California aimed at developing new control technologies and correcting the deficiencies of existing ones.

The U.C. research pursued an integrated concept involving physical, biological, cultural, and chemical methods. The natural enemies of mosquitoes—mosquitofish, aquatic insects, mosquito parasites, and pathogens—were studied; control by manipulation of mosquito genetics was explored; and selective insecticides were developed.

In support of the research, the state legislature appropriated $200,000





This tiny mosquito predator fish, Gambusia affinis (above), is the principal biological control agent in California. Below, a mass of the fish is being seined from a fish-rearing pond for distribution to mosquito-breeding places.

in fiscal year 1972, subsequently increased to $453,000 in 1977. The funds were to augment research grants to U.C. scientists from local, federal, and international sources, which totaled about $1,450,000 in 1976-77. The increased funding will make possible new levels of mosquito-control research.

Biological control

Biological control (biocontrol) aims to govern the mosquito population—in concert with other methods—on a continuing basis, in contrast with chemical control which provides an immediate and temporary effect.

Mosquitofish are the most widely used biocontrol agent in California mosquito control, but the lack of an economical overwintering rearing system has prevented realization of their full operational potential. One solution could lie in obtaining an industrial source of heated waste water in which fish are reared on a massive scale and supplied to control agencies in the quantities needed to meet their seasonal requirement.

Planaria are free-swimming flatworms which prey on mosquito larvae with devastating results to mosquito populations. Before attacking, the worm secretes a mucus that immobilizes the larvae. As with most biological agents, mass culturing techniques are needed.

Among the parasites and pathogens of mosquitoes, research has centered on nematodes, fungi, and bacteria, which have shown varying degrees of promise for eventual field use. One fungus parasite—*Lagenidium* sp.—has demonstrated survival capability under field conditions and high rates of infection in rice field and irrigated-pasture mosquitoes. In preliminary trials, several species of bacteria have shown promising results against the major pest and disease vector mosquitoes in California.

Other biological agents are being studied, but at present, apart from mosquitofish, none is considered operational as a replacement for pesticides.

Chemical control

Although many traditional chemical insecticides have fallen into disfavor because of mosquito resistance, Environmental Protection Agency restrictions, and high costs, chemicals are still indispensable in mosquito control. Research is continuing to improve existing compounds and to develop and evaluate new ones.

Pyrethroids are recently introduced insecticides which exert a toxic action similar to that of the plant derivative, pyrethrum. Besides being effective at dosage rates far below most other insecticides, they are relatively non-toxic to warm-blooded animals.

However, like the natural pyrethrum products, pyrethroids are highly toxic to fish and other aquatic animals, restricting their use to temporary mosquito breeding places unsuitable for fish and other non-target organisms.

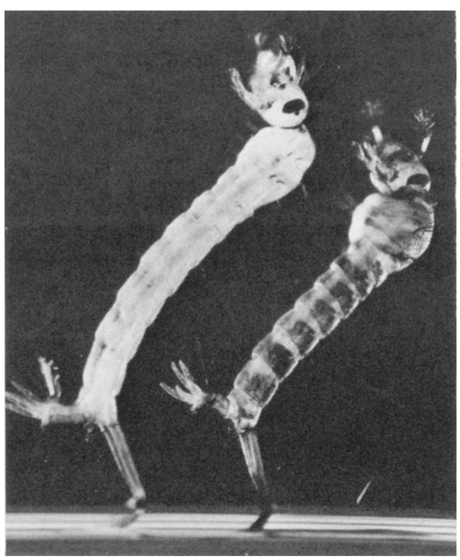
Insect growth regulators

These new compounds control mosquito larvae by interfering with the normal growth processes. Using extensive evaluations of Altosid and Dimilin in the laboratory and field, U.C. scientists reported excellent results against several species of mosquito larvae. The toxic action of the insect growth regulator (IGR) was selective to mosquitoes.

Predicting resistance

Resistance potential of mosquitoes against new pesticides is being evaluated at U.C. Riverside. In studies on new synthetic pyrethroid compounds, a strain of *Culex* mosquitoes developed a 4,000-fold resistance after repeated exposure for 16 generations to one type of pyrethroid. With another related compound, the rise was less rapid, attaining a 100-fold level in 22 generations. The laboratory results can indicate potential resistance problems, but not necessarily forecast the actual fate of the insecticide under operational use in the field.

Mosquito resistance to IGRs was also induced, but the level of resistance varied among the different IGRs from 200-fold to none at all with Dimilin.



An observable mutation (dark body) is a helpful tool for isolating radiation-induced genetic control mechanisms in the Culex tarsalis mosquito. Research is under way by the Department of Biomedical and Environmental Health Sciences in cooperation with the Department of Entomological Sciences.

Counteracting resistance

Studies indicate possibilities for reactivating insecticides against resistant mosquitoes by the addition of synergists. If proved feasible, the addition of synergists will have an enormous impact on reducing insecticide costs.

Furthermore, it was shown that resistance can be delayed or avoided by applying lower insecticide dosage levels, by alternating treatment schedules with different insecticides, by setting higher selection thresholds, and by allowing a small proportion of a mosquito population to remain untreated, thus preserving the susceptible genes.

Insecticide application equipment

It is usually more efficient to attack the mosquito in the larval stage. However, adult control must be resorted to when larval control fails because of resistance to insecticides or when mosquito operators cannot maintain adequate control of rice fields and other vast mosquito breeding areas.

To improve adult control, a cold fogger machine has been developed that emits insecticides in micron-size particles.

Genetic control

Past studies by U.C. scientists have confirmed *Culex tarsalis* as the main mosquito vector of Western Equine Encephalitis (WEE) and St. Louis Encephalitis (SLE). Recently U.C. researchers have confirmed through genetic studies that *Culex tarsalis* populations are made up of different strains, some of which are incompetent to transmit encephalitis while others, among a vast majority of resistant strains, are susceptible to insecticides.

To test the feasibility of genetic control, large numbers of genetically altered *Culex tarsalis* males were released in 1977 in an isolated area near Bakersfield to evaluate the insertion of the genetic flaw in the natural *C. tarsalis* population.

Encephalitis surveillance

As part of the encephalitis research effort, U.C. public health scientists are maintaining encephalitis surveillance in collaboration with the California State Department of Health and mosquito abatement districts to monitor the annual occurrence of virus and the distribution within the state. The surveillance serves as an early warning system for possible outbreaks of the disease and provides an overall statewide evaluation of the effectiveness of vector control programs.

Conclusions

Voluntary cooperation and collaboration between California mosquito control agencies and U.C. scientists on research projects are increasing. The close working relationship between the University of California and the control agencies has stimulated and strengthened the research program toward achieving a compatible, practical, and economical research effort. An indirect result of the research has been a gradual evolvement of new control strategies being adopted by mosquito control agencies throughout the state. Reliance on chemical control has faded appreciably in recent years, and the trend has shifted toward integrated pest management.

The shift is directly reflected in the records of insecticide consumption of mosquito control agencies. For example, in 1962—the peak year of pesticide application—615,000 pounds of insecticide were used by California control agencies compared with approximately 63,000 pounds in 1976, a tenfold decrease. Much of the reduction is attributed to more judicious and efficient use of chemicals and a shift to more effective oil-type formulations facilitated by University research.

Instead of oils being applied at dosage rates of twenty to fifty gallons per acre of mosquito breeding area, as in the past, control is equally effective at rates averaging two gallons per acre. As a result, labor and material costs have been cut deeply and environmental pollution is negligible.

Russell E. Fontaine is Extension Entomologist, University of California, Davis, and Charles H. Schaefer is Entomologist in the Experiment Station at the Fresno Mosquito Control Research Facility.

Exotic dung beetles in pasture and range land ecosystems

John R. Anderson Edmond C. Loomis

Because they rapidly bury cattle dung pads and thereby reduce pest fly breeding sites, selected species of exotic dung beetles are being imported and used as an integrated pest managment tool on California's pasture and range land. These beetles are being mass-produced and released in an attempt to simultaneously manage three pests: the horn fly and the face fly, which breed only in cattle dung, and the dried-out slabs of dung, which become pests that smother the growth of new vegetation for two to four growing seasons. Their digging also may improve pastures by accelerating nutrient recycling and by improving soil stability and permeability. Researchers in other areas also have found that dung beetles reduce the numbers of parasitic gastro-intestinal worms that infect cattle.

Beef cattle have been the leading monetary commodity in California agriculture for many years, with dairy cattle ranking second. This project could thus affect much of the 36 million acres of range land unsuited for other kinds of agriculture, as well as the 700,000 acres of irrigated pasture supporting both beef and dairy cattle. As noted recently by Extension economists, about 65 percent of the nearly three million beef cattle produced annually in California obtain all their feed from range land.

Exotic dung beetles are expected to represent a permanent, self-perpetuating type of pest management. They are now gradually dispersing and burying more dung pads as they expand their range. Because cattle (and bison) are not native to California, only a few of the native dung beetles have adapted to cattle dung. The small native beetles, unfortunately, have little impact on the vast quantities of cattle dung deposited each year.

The adverse economic impact of parasitic worms and horn and face flies on the cattle industry is well known, but it is not widely recognized that dried-out dung pads also are a major problem. Recent research, however, has revealed that non-degraded cattle droppings are economically important pests in California, comparable in importance to lice, ticks, or flies.

Effect on forage

Studies at a U.C. field station near Marysville have shown that because of the smothering of new growth and cattle's rejection of the rank growth surrounding pads, the non-degraded dung pads from one cow cause first-year grazing losses of nearly 0.30 acre, or about $4.50 per cow. At the rate of twelve, 10-inch dung pads per cow per day, a 5,000-acre ranch supporting 450 cattle loses about $2,000 in potential conversion of forage to weight