Progress in mosquito control

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Participants in anti-malaria crusade at Penryn and Oroville, California, in 1910. From left: Ben Bairos, Herbert Leak, Lawrence Woodworth, and Professor William B. Herms, in charge of Medical Entomology at the University of California, Berkeley. (*W. B. Herms Collection*)

A review of the historical documents of mosquitoes and mosquito-borne diseases in California reveals an absorbing and dramatic story of rampant malaria and hordes of mosquitoes tormenting the first immigrants and settlers before California gained statehood in 1851. Then, as now, mosquitoes as disease vectors and pests of humans and animals were most severe in the Central Valley of California, an immense, fertile region more than 500 miles long.

Malaria was imported into the Valley along the Sacramento River in 1832 by Hudson Bay Company fur trappers from Oregon. Once introduced, the disease spread rapidly among the Indians, decimating the tribes during an epidemic of explosive intensity in 1833. Epidemics were subsequently reported during the California gold mining of 1849-50 and also recorded by the U.S. Army Cavalry in the Sacramento Valley. After formation of the State Board of Health in 1880 attention was focused on malaria as a major health problem. However, no effective means of control existed until the turn of the century, when news reached California that human malaria was transmitted by the *Anopheles* mosquito.

The discovery marked the beginning of organized mosquito control as the means of preventing malaria and other mosquito-borne diseases. Among the many programs launched throughout the world at that time—including the classic campaign to control malaria and yellow fever mosquitoes in the Panama Canal—California was one of the first of the states to develop a control project in 1905. Ironically, the project was not for the purposes of malaria control but was sponsored by a local community club to abate severe infestations of salt-marsh mosquitoes, which were depressing real estate developments in the San Francisco Bay Area. The involvement of the University of California in mosquito control dates from this project, when Professor H. J. Quayle, at Berkeley, was called upon to provide technical assistance.

Later, in 1910, the first anti-malaria campaigns were organized to rid the Central Valley of the disease under the leadership of a University of California entomologist, Professor W. B. Herms, assisted by entomologist S. Freeborn and engineer H. F. Gray. These dedicated men, in cooperation with local public-spirited citizens and a few mosquito abatement districts, led a concerted 10-year campaign against malaria, which ended with the virtual elimination of the disease in California by 1921.

Although California has since experienced sporadic outbreaks of malaria, mainly centered in the Sacramento Valley, swift action by mosquito abatement districts working with local and state health services has proven sufficient to eliminate the disease in each instance. Malaria vigilance has been given a new impetus in recent years because of the rising number of cases imported into California from malarious areas in Africa, Asia, and Latin America. In 1979 over 270 imported cases were reported in California, and many of these were detected in areas of potential malaria transmission.

In 1930 the discovery of mosquito-borne virus encephalitis by University of California medical scientists reinforced the public health importance of mosquitoes in the state. Research on the transmission of this complex disease has yielded information essential for an effective control and preventive program.

An overview of the mosquito problem in California since the early period of settlement to the present reveals a process of dynamic change. Originally, mosquito populations resulted from springtime flooding of rivers and water courses fed by winter rain and melting snow from the nearby mountain ranges. The overflow in the Valley created extensive marshes, sloughs, shallow ponds, seepages, and other extremely favorable breeding sites for many mosquito species. With the gradual arrival of settlers in the fertile Central Valley beginning in the mid-nineteenth century, irrigated agriculture during the dry summer season emerged and prospered. The once free-flowing rivers were channeled between high levees, and adjacent, fertile river lowlands were cleared of extensive wooded areas, leveled, and put to the plow.

The once natural mosquito habitats typified by clear, fresh, shaded waters of the riverine systems were gradually replaced by habitats typical of irrigated lands. In California this was characterized by numerous, undrained, waste-water pools and weed-clogged ditches open to sunlight during the summer growing season, when high temperatures and low relative humidity prevailed. This drastic ecological alteration caused the once dominant mosquito species to be redistributed and replaced by mosquito species adaptable to irrigated agriculture.

Although man-made mosquito problems overwhelmingly prevail in California today, the situation continues to change with shifting patterns of agricultural production and the expansion of urban and suburban areas.

Period of insecticide dominance in mosquito control

From the beginning of the first project in 1905, the programs relied principally on chemical control, consisting of routine oil and pesticide spraying of mosquito-breeding habitats, and physical control, involving ditching, diking, filling, and other water management procedures. These measures were designed to reduce, eliminate, or prevent formation of mosquito breeding sources. The use of mosquito-predator fish became widespread after a successful introduction near Redding, California, in 1921. The integration of these three control practices, together with public education, formed the basis of the control programs conducted by 25 relatively small mosquito abatement districts up until World War II.

After the war, the state experienced a rapid population growth, accompanied by an unprecedented demand for land and water resources to satisfy the growing needs of agriculture, industry, suburban development, and recreation. Old mosquito problems were intensified, and new problems created on an enormous unforeseen scale. The traditional mosquito control was not sufficiently flexible to cope with the complex changes and the public demand for protection from mosquitoes and mosquito-borne disease.

At this critical juncture a new insecticide, DDT, became available after being hailed worldwide as a "miracle insecticide" for the feats of malaria and other disease-vector control achieved in the military campaigns of World War II. In addition to being an extremely effective insecticide at low rates, DDT provided a prolonged residual effect, maintaining its toxic properties for months after application. The traditional pre-World War II methods were largely suspended and mosquito control programs in California became increasingly dependent on a routine of spraying DDT and related compounds by hand and power equipment and by aircraft.

Although the insecticidal strategy generated spectacular progress in mosquito control and the suppression of mosquito-borne diseases, by 1954 the major pests and vector mosquitoes in California had developed resistance to DDT and to all of the associated hydrocarbon insecticides. The resistance problem had become so widespread that mosquito control agencies were considering returning to pre-war strategies.

The crisis was averted, however, by the timely availability of a new class of organophosphorous compounds. These very effective and economical insecticides were employed with considerable success for a decade thereafter but, as time was to prove, they too were susceptible to the same deficiencies as the organochlorines—that is, mosquito resistance, toxicity to natural enemies of mosquitoes in the aquatic habitat, and environmental contamination. As resistance levels in mosquito populations increased, more insecticide was needed until the law of diminishing returns rendered additional applications uneconomical.

Although new organophosphorous compounds were synthesized and marketed to replace resistant ones, the process leading to failure was inevitably repeated. By the late 1960s the high standards of mosquito control in California were again threatened. Even the possibility of a resurgence of mosquito-borne disease was seriously debated. Mosquito control had reached a crisis calling for drastic modifications in strategies.

Lacking proven alternatives to insecticides, however, control agencies could not shift their operations to noninsecticidal measures. During the 20-year period of preoccupation with insecticides, the development of alternative measures had seriously lagged. For example, the potential for biological control employing natural enemies of mosquitoes—predators, parasites, and pathogens—had received only superficial study. The great expectations of genetic control were virtually untapped. The possibilities of shifting from chemical insecticides to narrow-spectrum "biological" compounds that would kill resistant mosquitoes, while sparing their natural enemies, had not passed the exploratory stage. Causes of physiological resistance and methods for counteracting resistance provided a rich opportunity for applied research. Research and development of physical and cultural control were also urgently needed in the irrigated agricultural areas of California.

Mosquito control agencies urged and supported an expanded, accelerated program of goal-oriented research in the University of California. Methods had to be perfected to allow the agencies to shift from a unilateral pesticide-based operation (monocontrol) to a multilateral operation employing several measures consistent with integrated pest management concepts and practices.

In support of the University-wide research proposal, a special appropriation was approved by the state legislature in 1972, subject to annual review. In 1979 the special fund, including University expenditures and extramural grants for mosquito research, was approximately $1.5 million.

The impact of research in California has been reflected in a perceptible trend away from the use of pesticides toward biological and physical-cultural control methods. For example, pesticide use by California control agencies has declined 65 percent since 1970.

A substantial part of the reduction is attributed to judicious, efficient use of insecticides and a shift to more effective oil-type formulations developed by University research. In adopting an integrated mosquito control management, many agencies have learned to manipulate pesticide applications to avoid extensive destruction of nontarget organisms, spraying only when mosquito densities are sufficient to produce a pest or disease risk situation.

Since its inception the program has continued to benefit from the support and assistance of California Mosquito Abatement District (MAD) staff and the California Mosquito and Vector Control Association (CMVCA). Approximately 40 percent of the 60 MADs and other local control agencies are currently collaborating in mosquito research in several important ways: the conduct of independently funded research; grants to University of California researchers; and participation with University researchers in field trials, including cost-sharing through assignment of staff and contributions of transport, facilities, and materials. In addition, the CMVCA annually reviews research proposals and advises on research needs and priorities in the state. The close working relationship has strengthened the program and contributed to achievement of a compatible, practical, economical research effort.

The research reports presented in this issue reflect the comprehensive scope of the program and the coordinated interdisciplinary research in progress. As biological control and other alternatives to broad-spectrum insecticides are perfected, their use will eventually assume a dominant position in integrated control programs relegating pesticides to a minor role, such as spraying for vector disease control and other specialized purposes.

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