Carbon-dioxide light trap is used, along with other baited traps, to collect mosquitoes in studies of virus transmission.

Biology, and

Research on mosquito biology and ecology yields fundamental knowledge of the behavior, habits, breeding preferences, flight range, survival rates, and other characteristics of pest and disease-vector mosquitoes—information essential for effective planning and execution of control programs. Ecological studies assume greater importance in California than elsewhere because of the state's diverse climate and topography. Forty-nine mosquito species are found here, of which six are confirmed disease vectors.

virus transmission in the cooler months of September, October, and November.

The other abundant mosquito, *Culex erythrothorax*, fed on man but was virtually devoid of either SLE or WEE viruses, indicating that this species had no role in arbovirus transmission. Capture of *Culex pipiens quinquefasciatus* occurred only occasionally, showing that the habitat was unsuitable for this vector species.

Blood studies of adjacent feedlot cattle, a large native population of cottontail rabbits, and other wild mammalian species established that mammals played virtually no role in providing virus to *Cx. tarsalis*. The question of whether persistence of SLE-virus-infected populations of *Cx. tarsalis* for more than six months resulted from low-level cycling or survival of the early summer adults has not been resolved.

Two questions emerged from this research. First, what mechanisms resulted in periodic predictable reintroduction of SLE virus into the Finney focus? Second, from what vertebrate species did *Cx. tarsalis* obtain the virus?

Failure to catch *Cx. tarsalis* more than 100 meters from the vegetation associated with the Alamo River drainage in sufficient numbers to examine for virus suggested that the courses of the Alamo and New rivers, originating in Mexico and emptying into the Salton Sea, may be a conduit for the vertebrate-vector cycle of introduction from a permanent source further to the south—possibly not far away.

To examine the hypothesis, a sample area was staked out along the New River from the Mexican border 15 miles to the northwest. Light traps were placed at 1-mile intervals. Monthly collections (more frequently in warmer months) in 1976 and 1977 confirmed that virus appeared along this course. Simultaneous collections at Finney established a preliminary impression that SLE virus appeared in the Finney focus later. This was definitely established for WEE viruses in 1978.

Being an effluent outlet from Mexicali, the New River proved to be a favorable habitat for *Cx. p. quinquefasciatus*. The carbon-dioxide-baited mosquito light trap is not very useful for collecting *Cx. p. quinquefasciatus*. However, some pools caught in these and pigeon-baited lard-can traps yielded SLE virus.

With the appearance of sporadic human cases of SLE, most recently recognized in Mexicali, the evidence of human SLE infection in the Imperial Valley, and isolations of SLE from local populations of *Cx. p. quinquefasciatus*, the next problems to be solved became clear. Only when we establish mechanisms for annual reintroduction and movement along the Alamo and New rivers, the avian sources of virus to *Cx. tarsalis* mosquito vectors, and the crossover locale into local *Cx. p. quinquefasciatus* mosquitoes can effective control and preventive measures be defined.

More effective disease surveillance is needed, and some answers to these questions lie south of the border. Continued support of mosquito research in California can also lessen the threat of mosquito-borne virus disease in the state's richest agricultural domain, which is also becoming one of its most important recreational regions.

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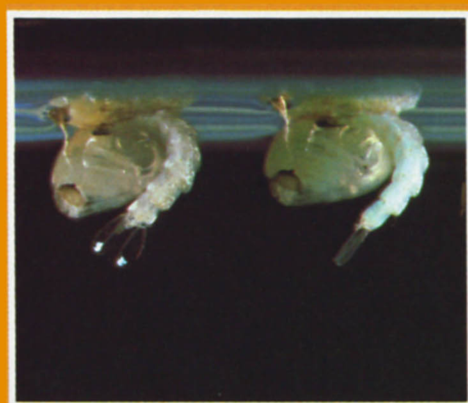
ecology, ethology

Photo by Chet Fukushima

Photo by Chet Fukushima



Mosquitoes — a by-product of rice culture

Robert K. Washino

Rice culture is a prime agricultural mosquito breeding habitat of concern to mosquito control agencies in northern California. It provides the major sources of the western malaria mosquito (*Anopheles freeborni*) and the encephalitis mosquito (*Culex tarsalis*). Since the end of the two-year drought and changes in federal rice allotments in 1977, the number of acres in rice production has increased from 308,000 in 1977 to 499,000 in 1978 and 534,000 in 1979. The cost of mosquito control in this considerable area has far exceeded the economic resources of most tax-supported, rural mosquito abatement districts.

Long-term studies conducted from 1954 to 1978 indicate a positive correlation between the mean annual index of adult female *An. freeborni* and rice acreage in Colusa ($p = <0.01$) and Sutter-Yuba ($p = <0.05$) counties. The ability of *Cx. tarsalis* to exploit larval habitats other than rice fields is probably the reason a similar correlation has not been observed with this mosquito.

Apart from the public health importance of *Cx. tarsalis* as an encephalitis vector and *An. freeborni* as a malaria vector, mosquito abatement district officials must also cope with the spread of *An. freeborni* from rice fields and other rural breeding sources to populated areas, where they are a nuisance pest during late summer and fall.

Studies were conducted from 1970 to 1975 concerning levels of public tolerance to major pest mosquitoes in communities near rice-growing areas of the lower Sacramento Valley. Information was collected on comfort/discomfort levels by means of personal and mail surveys of mosquito bite histories and related factors taken by student workers throughout the summer; interviews and examinations for mosquito bites by Public Health nurses on home visits and in well-baby clinics; and examination of records of service requests or complaints about mosquito nuisances to local mosquito abatement districts.

The relationship between degree of discomfort of the local residents and density of the pest mosquito population was analyzed. From 1970 through 1973 in Sutter and Yuba counties, *An. freeborni* accounted for the most complaints or service requests from urban residents, and *Culex* and *Aedes* species for such reactions from rural residents. When mosquito physiological age was included in the analysis, adverse public response to mosquitoes was most closely correlated with the older (parous) *An. freeborni* female population. Further analysis of the results will be useful in developing estimates of public tolerance levels and would be essential to a fully integrated pest management program for mosquito abatement districts.

Control technology

Depending on rice acreages and local resources available for a routine rice field mosquito control program, mosquito abatement districts have usually resorted to the following practices: aerial application of an organophosphate larvicide; early-season stocking with the mosquito fish (*Gambusia affinis*); ground application of nonthermal adulticides; or all three methods.

Collaborative studies with local and state agencies have been helpful in assessing alternative conventional and growth-regulating chemical agents for possible use in rice field mosquito control.

Investigation of physical control methods in rice fields has been limited to one two-year feasibility study. A single and double mid-season drainage to flush out mosquito larvae from rice fields showed promise in a water management study but requires further total impact studies.

Aquatic sentinel cages in rice fields are used to isolate larvae so that control strategies can be evaluated under field conditions.

Most of our recent efforts in rice field studies have been to develop biological control agents. The mosquito fish has been studied most extensively, and results are discussed in another section of this issue.

Investigations of aquatic insects as natural predators of mosquito larvae in rice fields revealed that, in most instances, the peak seasonal abundance of insect predators and mosquito larvae did not necessarily coincide sufficiently to be effective. A system of mass culture with subsequent introduction of aquatic insects into rice fields has not developed to the point of serious field evaluation.

With regard to other invertebrate predators, studies by other investigators on hydra in rice fields have so far been inconclusive. Field studies in Sutter and Yuba counties indicate that flatworms (Microturbellaria) are promising as predators in rice fields. However, further studies are needed to explain more precisely why rice fields containing numerous flatworms do not support heavy mosquito populations.

Control agents categorized as insect pathogens being evaluated for possible use in rice fields include two fungi, two bacteria, and a nematode. So far an aquatic fungus, *Lagenidium giganteum*, against *Cx. tarsalis* and a mermithid nematode, *Romanomermis culicivorax*, against *An. freeborni* have shown potential.

The ability of both agents to recycle in the rice field habitat from one growing season to another was recently demonstrated. *Lagenidium giganteum* has been recovered repeatedly (1974 to 1979) from previously experimentally inoculated seepage ditches adjacent to a rice field (1972) as well as from two experimental rice fields (1975-76; 1978-79). The successful recovery of *R. culicivorax* during the 1979 season after inoculation of the rice field in 1978 is encouraging. If the recycling pattern of the nematode can be confirmed and demonstrated on a large scale, the cost advantages of the fungus and nematode agents over repeated insecticidal applications would be enormous. An important consideration from an environmental impact standpoint is the minimal adverse effect of both agents on nontarget invertebrates and vertebrates. Whether they can be developed as fully operational biological control agents for rice field mosquito control will depend on a successful mass culture system and the ability of the agents to maintain viability and virulence with continuing changes in rice crop management practices.

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