pression might result on a continuing basis.

Evaluation of these fungi, like most other microbial control agents, is in an exploratory stage. Because these organisms are difficult to manipulate, progress has been slower than with insecticides and will continue to be so. None of the above species is likely to be operational within the next few years. Furthermore, to employ them effectively in IMC programs, new technologies must be developed, which will often have to be tailored to individual mosquito species. These technologies will be more expensive to develop and use than current technologies, but environmental costs will be lower because the fungi, unlike conventional insecticides, are highly specific. Although introduction of these fungi in some locations probably will provide moderate control on a continuing basis due to natural recycling, in most cases they will have to be reintroduced periodically. Nevertheless, it also will be important to evaluate the role each may play in IMC programs, as well as their potential if used unilaterally.

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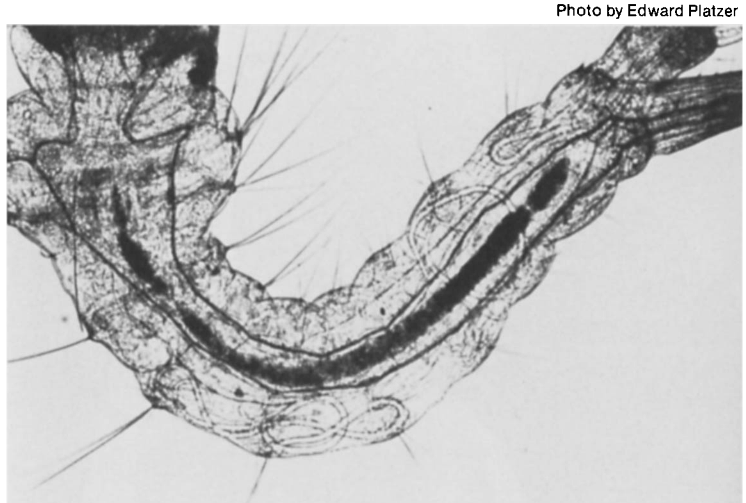
Nematodes as biological control agents

Edward G. Platzer

Photo by Edward Platzer



Culex pipiens larva 24 hours after exposure to the infective larvae of *Romanomermis culicivorax*. Four parasitic larvae are coiled within the body cavity.

A promising biological control agent against mosquitoes is *Romanomermis culicivorax*, a nematode parasite of mosquito larvae. The primary goal of research begun in 1973 was to determine the effects of environmental factors on the life cycle of the nematode so that procedures for mass-rearing and field releases could be improved.

A small scale mass-rearing system was established at University of California, Riverside, and initial studies were undertaken by Dr. B. J. Brown to define the effects of temperature, salinity, and oxygen on the infective stage of *R. culicivorax*. Preparasites infected *Culex pipiens* at temperatures between 12° and 33° C; the optimum range for infectivity was between 21° and 33° C. A temperature lower than 21° C decreased the infection rate but increased the time during which the nematodes remained infective.

An extensive study showed that at least half of the preparasites were able to infect mosquitoes at concentrations of salts usually found in fresh waters. Elevated calcium, nitrates, nitrites, and phosphates inhibited infection. The findings suggest that use of this parasite would be feasible in most fresh waters in North America.

The infectivity of preparasites depends on adequate oxygen levels. The low oxygen concentration in polluted water drastically reduces infectivity.

The parasitic stage developed within 6 to 28 days at temperatures from 15° to 32° C, a range that corresponds closely to the optimum for preparasite activity. Using heat unit calculations, one can predict the required time for the complete life cycle under natural conditions.

In temperature studies on postparasitic stages in outdoor ponds, adult nematodes developed, and a new generation of infective nematodes was produced within three weeks at an average ambient temperature of 27° C.

Mass-rearing of the nematodes was greatly improved by eliminating a contaminating fungus infection through an acid treatment of the cultures. This procedure will enable other laboratories and commercial facilities to propagate *R. culicivorax* more effectively.

In artificial and natural sites, *R. culicivorax* was field-tested against four mosquito species to study its effectiveness in California habitats. Infective nematodes were disseminated at approximately 1,000 per square meter of surface area. All species of mosquito larvae were infected; the percentage of infection depended on the mosquito subfamily and test site. In mixed mosquito populations, anophelines were more susceptible than culicines to parasitism. Dense vegetation or algal mats reduced mosquito larva control.

High populations of aquatic arthropods in rice fields prompted investigation of them as predators of the mermithid. Preparasites were attacked by copepods, cladocerans, young gammarids, and ostracods. Further studies with copepods in 1 liter of water demonstrated that 20 copepods significantly reduced mermithid infections of mosquitoes, and 53 copepods reduced the infection level by 50 percent. Thus, high densities of copepods in mosquito-infested waters may interfere with mosquito control by mermithid nematodes. Diving beetles, gammarids, dragonfly and damselfly naiads, and small crayfish avidly consumed *R. culicivorax* postparasites.

These findings indicate that temperature, salinity, oxygen, and the abundance of predators must be considered when selecting release sites for this mermithid. We conclude that *R. culicivorax* has good potential for anopheline mosquito control in California under suitable conditions.

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