

III. BIOLOGICAL CONTROL OF MOLE CRICKETS

Natural Enemies (R. I. Sailer)

Most organisms, whether plant or animal, have a variety of natural enemies. These include predators that consume their hosts and parasites that develop in or on the body of individual hosts and cause their death. There are also pathogens, such as certain fungi, bacteria, and viruses, that infect and kill their hosts (see next section).

No predators are known to depend entirely on mole crickets for their food supply, but in one genus of wasp the larvae of all species must develop as parasites of mole crickets. Mole crickets are also attacked by species of parasitic flies and by certain nematodes.

Predators

A surprisingly large number of vertebrate and invertebrate animals have been observed to prey on mole crickets. Crop contents of birds were studied in 1916 when mole crickets were very abundant in Puerto Rico. Results indicated that a variety of birds ate significant numbers of mole crickets and that over half the food of the Cuban green heron and more than a quarter of the food of the Puerto Rican sparrow hawk consisted of mole crickets. Toads, skunks, armadillos, raccoons, and foxes have also been observed to eat mole crickets.

A number of predacious insects also capture and destroy many mole crickets. These include carabid beetles of the genus *Calosoma*, tiger beetles of the genus *Tetracha*, and an elaterid beetle belonging to the genus *Pyrophorus*. Assassin bugs of the species *Sirthenea carinata* have been reported to be abundant in areas where mole crickets were numerous and have recently been observed to attack and feed on these insects in the laboratory. Even the imported fire ant acts as a predator on mole crickets.

Parasites

Before discussing parasites in greater detail, attention should be called to some confusion relating to use of the term *parasite*. As used by parasitologists the term is applied to organisms that live in or on hosts without causing their death. The parasite is normally very much smaller than its host and belongs to a very different taxonomic

group. Both adult and immature stages live in the host; for example, round worms and tape worms that parasitize man and other vertebrates. When entomologists use the term parasite, they generally are referring to an organism that kills its host and is parasitic only in the immature stages. The adults are free living, and most are insects that attack other insects. The following discussion focuses on parasites of this type.

Known parasites of mole crickets belong to three groups: digger wasps of the genus *Larra*, parasitic flies of the genus *Euphasiopteryx*, and entomophagous nematodes.

Digger wasps Wasps of the genus *Larra* (family Larridae) are the most specialized natural enemies of mole crickets now known. Unlike other digger wasps, which are generally predators, all species are parasitic. Worldwide, 65 species of *Larra* are known. Most are inhabitants of the tropics. Only one species, *Larra analis*, a parasite of the northern mole cricket, is native to the United States. Sixteen species have been recorded from South America, where the variety of species of mole crickets belonging to the genus *Scapteriscus* is greatest.

Much of what is known of the behavior and biology of larrid wasps is the result of mole cricket invasions of Hawaii and Puerto Rico. In Hawaii in the early part of this century, African mole crickets were causing serious damage to newly planted sugarcane. When an entomologist was sent to Australia, southeastern Asia, Africa, and South America to find natural enemies suitable for introduction, he discovered 12 species of *Larra* that develop as parasites of mole crickets—2 from Australia, 3 from the Philippines, and 7 from South America. One species, *L. luzonensis*, was successfully introduced into Hawaii. Unfortunately, little is known of the consequences, other than what might be inferred by diminished interest in and present absence of concern about the economic importance of mole crickets in Hawaii.

In Puerto Rico, mole crickets thought to have been introduced in guano shipped from South America were the most injurious agricultural pest from 1876 to 1902. They remained a serious problem at least until the 1930s, when Puerto Rican entomologists introduced *Larra bicolor* from Brazil. By 1938 this wasp was successfully established, and by 1942 it occurred throughout the island. Again, there is no documented assessment of results.

Apart from preferences for different species of mole crickets, the biology of the various species of *Larra* is remarkably similar. Females do not construct a nest, and prey paralysis is temporary with the host reviving soon after egg deposition (Fig. 16a). The *Larra* larva

lives ectoparasitically until almost full grown (Fig. 16b). It then kills and consumes the rest of its host (Fig. 16c). *Larra* females lay about 30 eggs in their life span. Full-grown larvae form underground cocoons of sand grains cemented together with a secretion from the labial glands. In the case of *L. bicolor* the adult wasps emerge from their cells 60 to 80 days after eggs are laid on the hosts. At Fort Lauderdale, where 88 females from Puerto Rico were released in early June 1981, three generations were produced by December. In 1982, the first adults were seen in March. Thus, at least four generations are probably produced annually at that location.

The behavior of adults of several *Larra* species has been studied, and all species exhibit the same general pattern. Females hunt for mole crickets during early morning and mid-afternoon hours. During the middle of the day they visit flowers where they feed on nectar and possibly pollen (Fig. 16d). The different species not only have individual preferences as to kind of mole cricket they parasitize, but they also tend to frequent the flowers of different plant species. For example, adults of *L. bicolor* are most commonly found on the flowers of two quite unrelated plants, *Spermacoce verticillata* (Rubeaceae) and *Hyptis atrorubens* (Lamiaceae). The close association of *L. bicolor* with these plants in Brazil and Puerto Rico suggests that it may not inhabit areas where these plants are not available. At the site in Fort Lauderdale where *L. bicolor* is now established, several small plots of *S. verticillata* were planted and were blooming when the wasps were first released. These plots have since been used to monitor the presence and increase of the wasp population.

Fortunately, *S. verticillata* is native to south Florida; however, in order for *L. bicolor* to become an effective enemy of mole crickets in central and northern Florida, it may be necessary to establish *S. verticillata* or other suitable flowering plants in areas where mole cricket populations are high.

Tachinid flies All species of true flies of the family Tachinidae develop as parasites of other insects. Some groups of species are restricted to closely related kinds of host insects; for example, the group Ormiini consists of species that parasitize katydids and other night-singing Orthoptera. The best known species of this group, *Euphasiapteryx ochracea*, has been attracted to the tape-recorded song of the southern mole cricket, though its normal hosts are field crickets. Although larvae dissected from female *E. ochracea* and placed on adult southern mole crickets have developed successfully, none have been reared from field-collected mole crickets in the United States. However, small numbers of a related species, *E. depleta*, have been reared from mole crickets collected at Belem,

Brazil, and there is a high probability that other South American species of the genus *Euphasiopteryx* are specialized as enemies of mole crickets and can profitably be introduced into the United States.

Nematodes Among the several subgroups of nematodes that are known to parasitize insects, the families Mermithidae and Steinernematidae are especially likely to include natural enemies of mole crickets.

The mermithids are widely distributed in aquatic and terrestrial habitats and attack a wide range of insects and other arthropods. The fact that certain genera are commonly restricted to specific groups of insects suggests that a careful search of the homeland areas of *Scapteriscus* will reveal one or more species of mermithids that should be introduced into Florida. *Agameris decaudata*, a parasite of grasshoppers, is an example of this group. After emerging from a dying host they normally go into the soil, molt to the adult stage, and mate. The female then lays eggs on vegetation to be eaten by feeding grasshoppers.

The insectivorous nematodes of the family Steinernematidae behave differently from the mermithids. Instead of developing singly in hosts, the infective juvenile stage introduces a symbiotic bacterium into the host. The bacterium causes death of the host in about 24 hours. The nematodes complete their development in the host cadaver and mate; the females lay very large numbers of eggs that quickly hatch to produce second generation adults. The offspring of these adults convert the host cadaver into a mass of juvenile nematodes that seek out new hosts. Within this group, species of the genus *Neoplectana* are probably of greatest interest for purposes of mole cricket control.

In addition to recent discovery in South America of a mole cricket infected by a species of *Neoplectana*, there is another reason for interest in these nematodes—they can be cultured on artificial media, and one species, *N. carpocapsae*, is currently produced commercially for control of soil insects and wood tunneling insect larvae. Research is now in progress to determine whether strains of *N. carpocapsae* or other species of *Neoplectana* may prove useful when applied as a biocide for immediate control of mole crickets.

Past and present research on natural enemies of Florida's mole crickets

During the 1930s mole crickets became a serious economic problem in central Florida, and research on their biology and control was undertaken shortly before the outbreak of World War II. At this time

some attention was given to natural enemies. Most were incidental predators that had no demonstrable effect on mole cricket populations. However, two kinds of pathogenic fungi were found, one of which (*Syngliocladium urella*) was thought to materially reduce populations of the tawny mole crickets.

There appeared to be no effective native natural enemies in Florida; however, *L. bicolor* had recently been introduced into Puerto Rico, and an attempt was made to introduce that wasp into Florida. Work was started in 1941 and disrupted by the war. Following the war, an effort was made to obtain stock of *L. bicolor* from Belem, Brazil, and in 1947 one shipment of 138 adults and 40 parasitized mole crickets was received. All adults and all but one of the parasitized crickets were dead on arrival.

At this same time, as a result of the discovery of DDT, entomologists were shifting their attention from biological to chemical control. Other highly effective insecticides, including chlordane, were soon discovered. In 1949, the annual report of the Florida Agricultural Experiment Station noted that research on biological control had been terminated because tests had shown DDT and chlordane to be highly effective against mole crickets and these were recommended for control.

Research on biological control was not resumed until 1978, when the present mole cricket project was initiated. Since both the tawny and the southern mole crickets were thought to be of South American origin, the best approach to biological control would have been work in South America to discover areas of origin and associated natural enemies of the species that invaded Florida and other areas of southeastern United States. When found, enemy species could then be studied and evaluated as candidates for introduction before being sent to Florida for further study and field colonization. With limited resources this was not initially possible; however, *L. bicolor* could be obtained from Puerto Rico where it had been introduced in 1938. Although no new information regarding the wasp had been published since 1942, correspondence with Puerto Rican entomologists indicated that it was commonly seen at several locations on the island.

Successful introduction of *L. bicolor* into Florida from Puerto Rico appeared unlikely because the colonizing stock used to establish the species in Puerto Rico came from Belem, Brazil, a city located almost on the equator. In the history of biological control no beneficial species native to the equatorial zone has been successfully introduced into regions of temperate climate. But, since it was not yet possible to undertake work in South America, and gaining experience with *Larra* was judged important, study of *L. bicolor* was begun.

Beginning in 1978 annual trips were made to Puerto Rico to learn where to find and how to collect and ship adult *Larra*, as well as to obtain information about behavior of the wasps and about their host mole crickets. Plantings of *S. verticillata* were established at Gainesville, Fort Lauderdale, and elsewhere in order to create conditions favorable for field colonization of *Larra*.

Experience gained during 1978–1980 made possible the successful establishment of *L. bicolor* on a golf course in Fort Lauderdale in 1981. Introductions at Gainesville, Tampa, and Bradenton failed. The colony at Fort Lauderdale increased during the summer and fall of 1981, and weekly counts of adults on 12 small plots of flowering *Spermacoce* indicated that the population doubled in 1982. The increasing trend continued during the spring and summer of 1983. Unfortunately, in late summer, except for a narrow strip bearing the *Spermacoce* plantings, the golf course was treated with ethylene dibromide (EDB) and the *Larra* population dropped abruptly to a very low level. By winter it had partially recovered.

Apart from continuing observation of the *L. bicolor* population at the Fort Lauderdale site, domestic research has concerned the biology and behavior of the wasp. In June 1983, 83 female wasps collected in Puerto Rico were released at prepared sites on Ram's Horn Ranch in Hillsborough County. A second release, consisting of 47 females, was made in December. Ram's Horn Ranch has been selected as the principal field location for future release of promising enemy species because it has a large acreage of bahiagrass pasture heavily infested with mole crickets and is centrally located with respect to the mole cricket problem. Also, a cooperative management together with the high cost of chemical control insures against disruptive actions of the kind that jeopardized continuance of *L. bicolor* at Fort Lauderdale.

For reasons already indicated, little work was done in South America during the period 1978–1982. However, information derived from taxonomic study of museum specimens pointed to the Rio de la Plata area of South America as the source of the mole crickets responsible for Florida's pest problem. This was supported by survey of Uruguay and Buenos Aires Province, Argentina, in late October and early November 1980. Additional evidence was obtained indicating that both tawny and southern mole crickets occurred in Uruguay and northern Argentina.

The foreign research effort was increased during 1981 when an agreement was negotiated with Professor A. Silveira-Guido of Montevideo, Uruguay, who then began studies on mole cricket biology and on natural enemies. During 1982, through operation of sound traps simulating the calling songs of Florida tawny and southern

mole crickets, he obtained further proof of the conspecificity of the populations in Florida and Uruguay. He also collected two species of *Larra* wasps, subsequently identified as *burmeisteri* and *gastrica*.

With funds from USDA, it was possible in 1982 to augment the foreign research effort through employment of a postdoctoral research entomologist with extensive South American experience. From mid-October to the end of December 1982, he visited Brazil, Uruguay, Argentina, and Paraguay to select a location from which to conduct a two-year study of natural enemies associated with mole crickets in South America. After taking into account such factors as access to field populations of mole crickets, availability of support facilities, and proximity to an international airport, he concluded that the Instituto de Biociencias, Universidad Estadual de Sao Paulo, at Rio Claro, S.P., Brazil was best suited as a location from which to conduct his research. In July 1983, he moved to Rio Claro and started his research program.

Future research on natural enemies

During the period 1978–83 much was learned regarding the biology and behavior of mole crickets. The identity, distribution, and area of origin was established for the three species of *Scapteriscus* now found in Florida. Apart from information acquired from literature, much less progress was made in learning of natural enemies of mole crickets and in determining which species are suitable candidates for introduction into Florida. As a result of USDA funds awarded to the project in 1983, it should now be possible to obtain this information as well as to collect or rear stock of promising enemy species. This is the primary objective of the research centered at Rio Claro, Brazil.

While efforts will be made to find and assess the potential value of all organisms that attack species of *Scapteriscus* in southern Brazil, Uruguay, and adjacent areas, present knowledge indicates that the most useful candidates for introduction are likely to be found among those that are parasitic or pathogenic. In the case of the parasitic wasps of the genus *Larra*, there is the possibility of a high degree of host specificity, with each species specialized to attack a single species of *Scapteriscus*. It may be that more than one species will have to be imported and colonized. If found and successfully introduced, these wasps should bring about a very substantial reduction in mole cricket populations. However, this cannot be accomplished quickly. With currently available resources and expertise, additional enemy species should be found, evaluated, and introduced by 1987. Additional

time will be needed to insure that they are distributed throughout Florida and to allow their effects to be evaluated.

Future studies of *L. bicolor* will involve efforts to colonize it at other locations in south and central Florida. Effort will also be made to obtain information on host range, dispersal, and other factors that influence its population numbers and effectiveness as an enemy of mole crickets in Florida. These same studies will be undertaken on other species of *Larra* as well as on other kinds of mole cricket enemies as these are found in South America and shipped to Florida.

For immediate biological control, particularly on golf courses and other high-value land areas, nematodes of the genus *Neoaplectana* and pathogens show the greatest promise. Here, more time is likely to be required in the research phase, but if an effective agent is found, it can be quickly exploited.