CHAPTER 7

Insects: Lepidoptera (Moths)

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Introduction

A number of moth species attack the products of honey bees—honey, pollen, and wax. Included are the greater and lesser wax moths (*Galleria mellonella* [L.] and *Achroia grisella* [Fabricius], respectively); several species that are primarily pests of stored products, the Indian meal moth (*Plodia interpunctella* [Hubner]), the Mediterranean flour moth (*Anagasta kuehniella* [Zeller]), and the driedfruit moth (*Vitula edmandsae serratilineella* Ragonot) (Milum 1940a, Singh 1962, Smith 1960). Death's head moths (*Acherontia* species) occasionally feed on honey and nectar (Brugger 1946, Raw 1954, Smith 1960). The bumble bee wax moth, *Aphomia sociella* (L.), is a rare pest of honey bee colonies (Toumanoff 1939).

In the developing countries of the world, additional undescribed moth species probably exist and will become pests of honey bee products, perhaps serious ones, as beekeeping in those areas intensifies.

Greater Wax Moth

Many people outside the beekeeping arena consider the greater wax moth, *Galleria mellonella* (L.), to be a useful insect. Larvae are raised commercially in the northern United States and Europe for sale as fish bait. They are also used for studies of physiology, toxicology, and pathology, and as an artificial host for the mass propagation of dipteran and hymenopteran parasites (DeBach 1964, Marston, Campbell, and Boldt 1975). However, the greater wax moth is by far the most important moth pest of honey bee products. It causes serious losses to commercial beekeepers every year (Eckert 1951, Singh 1962, Smith 1960). Whenever honey bee colonies become weakened or die during warm weather, *Galleria* larvae may quickly reduce the combs to a mass of webbing and debris. Conditions that render colonies susceptible to wax moth depre-

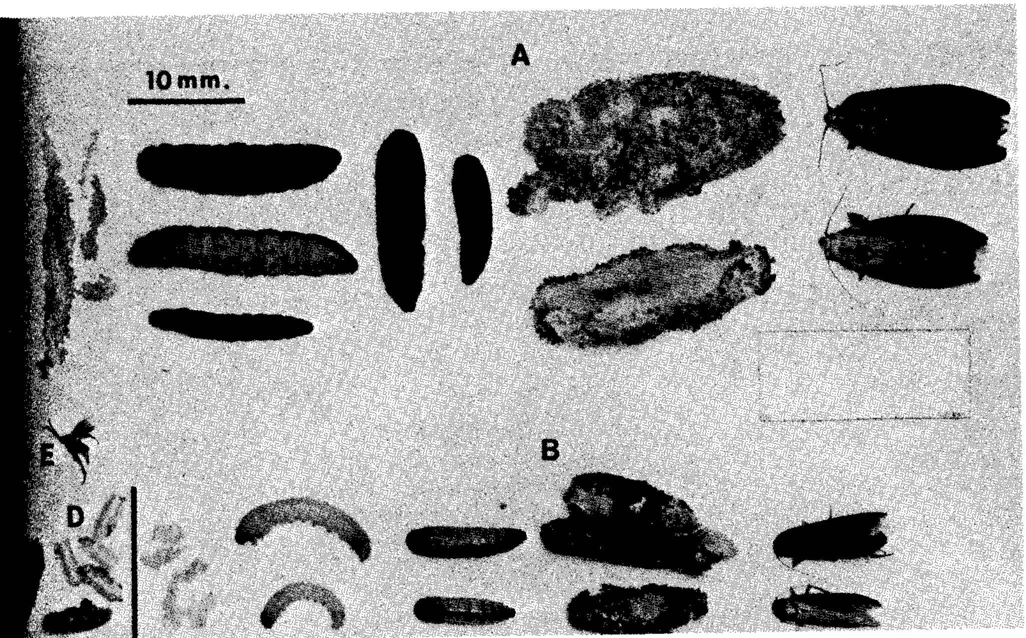

Figure 7.1. Stages of the greater wax moth, the lesser wax moth, and a parasitic wasp, *Apanteles galleriae*, which attacks young larvae of both moths. Eggs, larvae, pupae, cocoons, and adults of the greater wax moth (A) and the lesser wax moth (B). (C) Cocoons spun prematurely by young greater wax moth larvae that have been parasitized by *Apanteles galleriae*. White cocoons (D) and adult (E) of *Apanteles galleriae*. (Photo by M. Burks)

dation include lack of food, disease (especially American foulbrood), failing queens, queenlessness, and marked reduction of the worker bee population as a result of pesticide poisoning. In warm climates, the beekeeper must prevent colonies that dwindle during periods of dearth from being destroyed by *Galleria* (Sechrist 1944). The destructive activities of the greater wax moth are most severe in the tropics and subtropics, presumably because the species evolved in similar habitats in southern Asia along with honey bees (Morse 1975b).

Presently, in different parts of the world, many millions of combs are fumigated at the close of each beekeeping season as protection against wax moth damage. A typical thousand-colony beekeeping operation in the United States averages about 57,000 drawn combs (Anderson 1969), half or more of which are in storage for about six months out of each year. In the warmer sections of the country, protection of these combs against moth pests and other elements is a vitally necessary part of the beekeeper's management program.

In addition to *Apis* colonies, the greater wax moth infests the

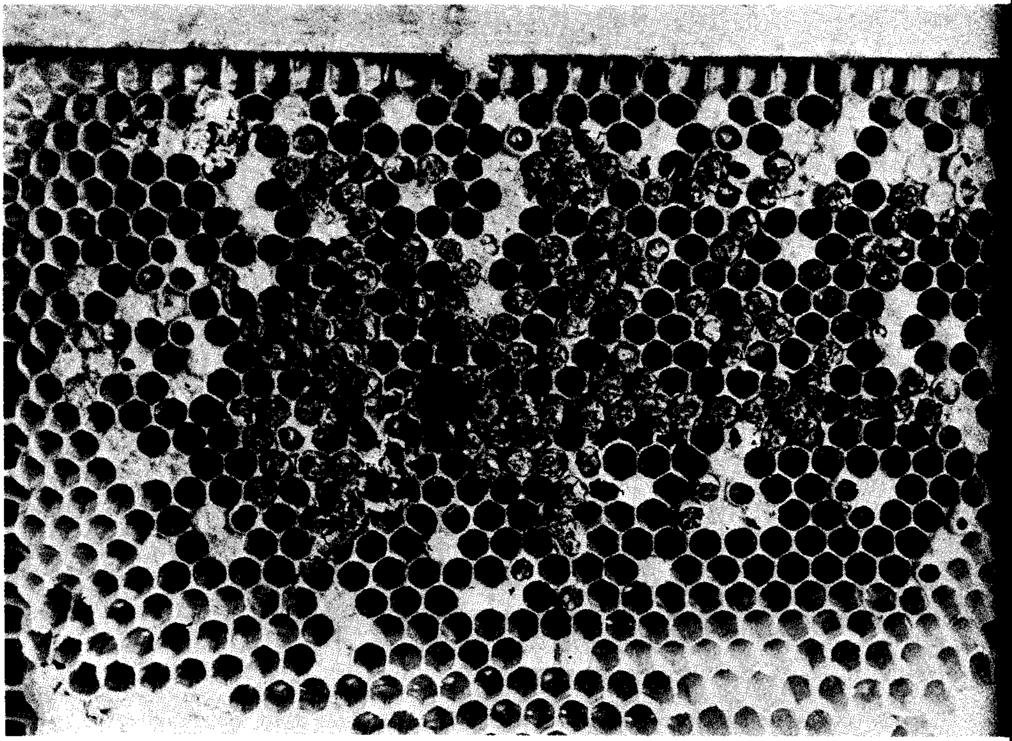

Figure 7.2. Emerging worker honey bees (*Apis mellifera*) afflicted with galleriasis. The adult bees were unable to leave the brood cells, being tethered by their abdomens to the comb with silken threads spun by small *Galleria* larvae. The comb was taken from a nucleus hive at Baton Rouge, Louisiana, during July. (Photo by M. Burks)

nests of the so-called stingless bees and bumble bees (Noguiero-Neto 1953, Oertel 1963).

Distribution

The greater wax moth occurs throughout the world almost everywhere honey bees are kept. Its distribution is limited mainly by an inability of the species to tolerate prolonged subfreezing temperatures. Little or no damage occurs from *Galleria mellonella* (L.) at high elevations (Paddock 1926). For example, natural infestations of beekeeping equipment have not occurred for over 40 years at Laramie, Wyoming.

Economic Importance

Apparently there are no data concerning monetary losses caused by the greater wax moth in major honey-producing countries other than the United States. Even in the United States few attempts have been made to assess the economic significance of this important pest of the beekeeping industry. Paddock (1918) assumed the number of hives of comb destroyed in Texas by *Galleria* to be approximately 5 per cent annually (14,000 units), and Oertel (1969) estimated annual losses in Louisiana to be approximately 31,000 dollars. In the United States *Galleria mellonella* (L.) presently causes extensive losses in the areas that produce the most queens and package bees (Gulf Coast states, Georgia, and California), where the climate is warm. Based on a survey of 114 southern commercial and semicommercial beekeepers who operated over 180,000 Langstroth colonies and over 250,000 queen-mating nuclei, *Galleria*-caused losses in the United States were estimated to be about three million dollars or more during 1973 and about four million in 1976 (Williams 1976). Losses in the three main beekeeping states in the south averaged nearly $1.00 per colony in California, $1.50 per colony in Texas, and $3.00 per colony in Florida.

Annual losses from American foulbrood in the United States, including operational costs for state apiary inspection programs, probably reach five million dollars or more. Wax moth losses may approach those caused by American foulbrood nationally and equal or exceed them in the states covered by the survey.

Morphology

Newly hatched *Galleria* larvae have a creamy-white body color that becomes gray to dark gray on the dorsal and lateral surfaces in older larvae; strains of larvae that are white-bodied at maturity have been bred commercially in the United States. *Galleria mellonella* (L.) larvae are the largest of the comb-infesting Lepidoptera, reaching as much as 28 millimeters in length and 240 milligrams in weight (Hase 1926).

Greater wax moth cocoons are usually bare and white, but some are almost completely covered with dark fecal pellets and frass; they usually are 12 to 20 millimeters long and about five to seven millimeters in diameter. Often the last-instar larvae migrate from the feeding site and spin cocoons on hive bodies or the inner cover. Large sheets of several thousand cocoons or more are a distressingly familiar sight to beekeepers in warm climates, including those in the southeastern United States. As many as 10,000 cocoons may be found in a two-story, 10-frame Langstroth hive, but normally only about 250 normal-sized larvae are able to develop on a dark brood comb (frame size: 447.7 × 231.8 millimeters) (Nielsen, personal communication, 1975).

Adult *Galleria mellonella* (L.) are heavy-bodied, fairly small moths. The females range in length up to about 20 millimeters and average as much as 169 milligrams in weight (Marston and Campbell 1973); the males average considerably less. In addition to usually being smaller, male moths may be distinguished from females by their lighter color and the distinctly scalloped apical margins of the forewings. Also, the female's labial palps extend forward giving the head a beaklike appearance. The anterior two-thirds of the forewing of normal adults of both sexes is rather uniformly dark, but the posterior one-third has irregular light and dark areas interspersed with darker streaks and uneven spots. Dorsally the thorax and head are light-colored. Both sexes vary considerably in size and color according to larval diet. Silver-white adults have been reared from wax foundation, whereas those reared on a diet of brood comb are colored predominantly brown to dark gray to almost black (Whitcomb 1936, Milum 1940a). *Galleria mellonella* (L.) adults may be smaller than some adult lesser wax moths if the larvae have developed slowly as a result of poor diet and low temperatures.

Adult Biology

The life cycle time for wax moths varies from four weeks to six months; in the case of the longer time, dormancy occurs in the prepupal stage (Marston, Campbell, and Boldt 1975). The adults require neither food nor water. The female begins laying eggs within about four to ten days after emergence and she produces about 300 to 600 eggs, though individual moths may lay up to 1,800 eggs (El-Sawaf 1950).

Adult *Galleria* live from three to over 30 days, but most mated females die within seven days when held at 30° to 32° Celsius (El-Sawaf 1950, Nielsen 1971). The lifespan of the wax moth is greatly increased at lower temperatures. The female lifespan averages 3.8 days at 40° Celsius and 19.6 days at 20° Celsius (Marston, Campbell, and Boldt 1975).

Galleria Eggs

The eggs of the greater wax moth vary in color from pinkish to cream to whitish. They are quite difficult to detect with the naked eye even though most are glued together in sheets of 50 to 150 eggs each. Undoubtedly the female moths' habit of depositing eggs

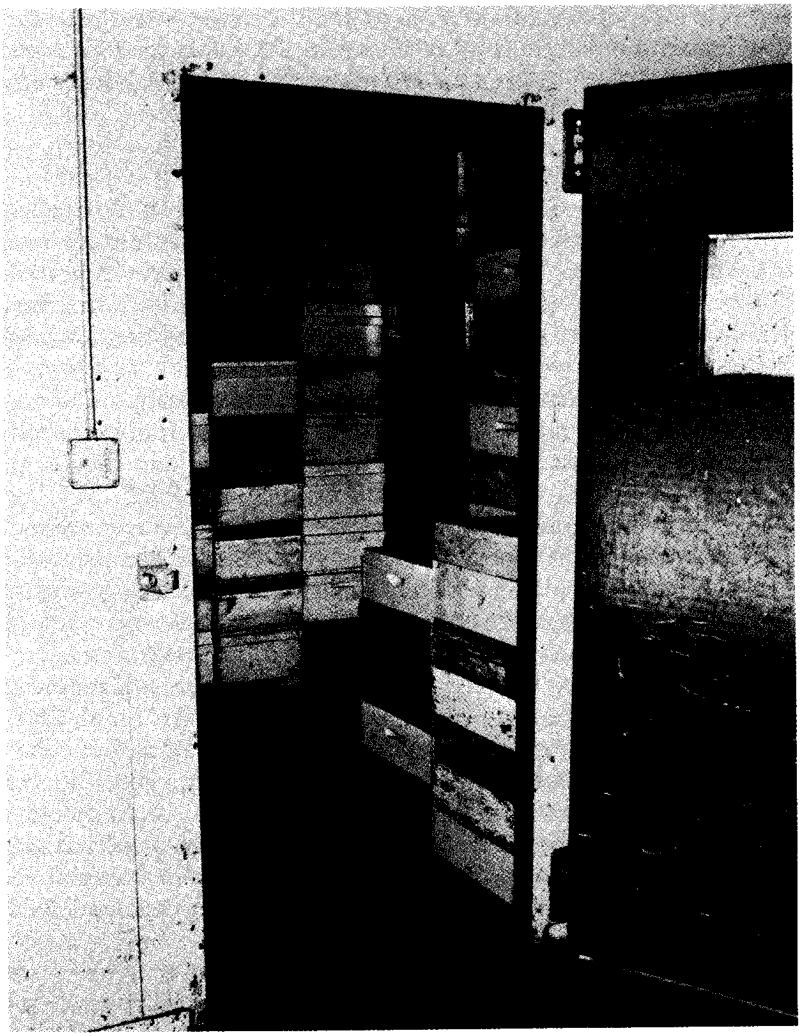

Figure 7.3. Air tight chamber used at the University of California, Davis, for the fumigation and storage of combs between seasons. (Photo by K. Lorenzen)

in small cracks and crevices that barely admit their ovipositors affords considerable protection against removal by worker bees and predation by other insects (Makings 1958, Milum and Geuther 1935).

Eggs develop rapidly when held at warm temperatures (29° to 35° Celsius) and begin to hatch within three to five days of oviposition (Dutky, Thompson, and Cantwell 1962, Nielsen 1971). Egg hatch is extended to about 30 days at 18° Celsius. Short exposure to temperature extremes (at or above 46.1° Celsius for 70 minutes and at or below 0° Celsius for 270 minutes) will cause 100 per cent mortality of eggs (Cantwell and Smith 1970).

Galleria Larvae

Upon hatching, *Galleria* larvae feed on honey, nectar, or pollen, if available, for their first meal. Typically, the larvae then burrow into the outer edge of cell walls or into pollen contained in cells. Developing larvae extend their tunnels to the midrib of the comb where they continue to feed and grow, protected from worker bees.

Larvae of the greater wax moth grow at an unusually rapid rate. If diet and temperature are favorable, they can double in body weight daily for the first ten days after hatching, and they begin to spin cocoons as early as day 18 or 19 (Beck 1960). This fast rate of growth accounts for the fact that all of the combs in a honey bee colony are often destroyed within 10 to 15 days after the adult bee population has been severely depleted by poisoning or other causes. As a consequence of this rapid growth, *Galleria* larvae produce substantial quantities of metabolic heat; temperatures as high as 25° Celsius above the environmental temperature are produced in the center of aggregations of larvae (Roubaud 1954, Smith 1941).

In spite of their extremely rapid growth under optimum conditions, *Galleria* larvae are also capable of surviving even if food is available intermittently or if they feed continuously on a marginal diet. Under such conditions, the total developmental period (egg to adult) is greatly extended—up to six months or so—and the adults are progressively smaller (Marston, Campbell, and Boldt 1975, Milum and Geuther 1935).

Developing larvae feed upon practically all of the honey bee products in the colony. Dark combs are especially preferred whether they contain honey, pollen, or both. Bee brood (larvae and pupae) also will be attacked if *Galleria* larvae are short of food (Milum 1935, Paddock 1918, Whitcomb 1936). In warm climates, many larvae often develop in the pillars of wax and in the pollen and debris on the bottom board of the hive.

Comb honey and freshly extracted combs may be quickly destroyed or heavily damaged if not properly handled when removed from the hive. In subtropical and tropical climates, *Galleria* larvae often infest impure cakes of beeswax, slumgum, and wax cappings. In addition, honey bee breeders operating in warm climates must protect beeswax associated with queen-rearing materials (wax cell cups, wax on wooden cell cups, and so forth) from damage by *Galleria* larvae. Honey bee-collected pollen that is isolated from combs and other forms of beeswax apparently is not attacked.

Although their natural diet almost always includes beeswax, *Galleria* larvae usually do not complete their development on refined wax, such as foundation, or on the new wax of comb honey (Milum 1940a). In the laboratory, the greater wax moth adapts readily to a variety of beeswax-free diets containing cereal products (Marston and Campbell 1973, Marston, Campbell, and Boldt 1975).

Crowding and lack of food cause *Galleria* larvae to become cannibalistic, and the larger larvae will devour smaller larvae, prepupae, and pupae.

Galleria-caused Absconding

Wax moth depredation is one of the common causes of absconding by *Apis mellifera adansonii* colonies in South Africa, along with overheating, lack of water, and attack by other pests. Whenever colony populations decrease sufficiently to expose combs, wax moth larvae develop unhindered and gradually attack combs occupied by *adansonii* bees, causing the host colony to abscond (Fletcher 1976).

According to Singh (1962), *Galleria* are a pest of almost all colonies of *Apis cerana, Apis dorsata,* and *Apis florea* in India. In that country, larval *Galleria* populations often become so damaging during dearth periods or monsoon seasons that infested honey bee colonies abscond. Wild colonies and deserted combs of *Apis dorsata* and *Apis florea,* in addition to managed colonies of *Apis cerana,* stored combs, and improperly cleaned wax are a constant source of wax moths there. *Galleria* are also common residents of active *Apis dorsata* colonies in the Philippines: populous colonies are lightly infested, whereas weaker colonies and abandoned nests contain many larvae (Morse 1975b, Morse and Laigo 1968).

Galleriasis

During the warmest months of the year when *Galleria* populations are largest, honey bee queen breeders operating in the southern United States quite commonly observe patches of apparently normal emerging workers and drones that are unable to leave the cells of combs in miniature queen-mating nuclei. After chewing away the cell cappings, the bees remain trapped in their

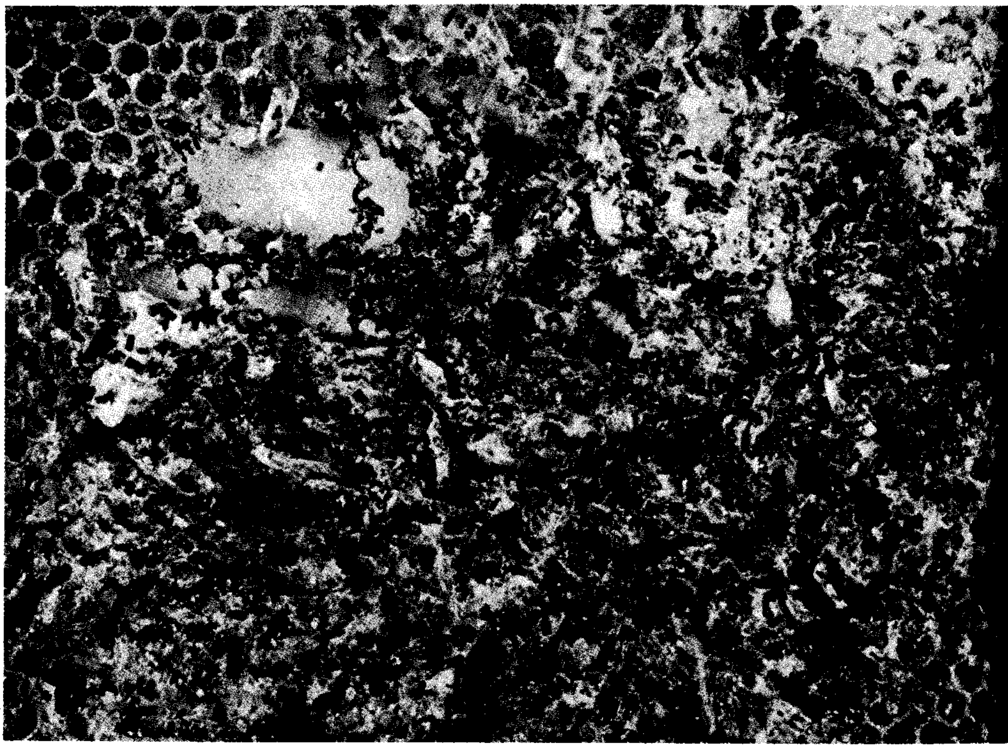

Figure 7.4. Close-up of new comb heavily damaged by the greater wax moth. (Photo by R. A. Morse)

cells by silken threads that *Galleria* larvae have spun at the cell bases. Entire combs of worker bees that have developed from brood of nearly the same age may be observed thus trapped with their legs flailing the air. Dissection of combs containing affected bees reveals one to three *Galleria* larvae near the bottom of most cells. This situation also can occur in frames of brood in Langstroth colonies, especially with the first generation reared in newly drawn combs (Nielsen, personal communication, 1975). The fate of bees suffering from this condition is unknown, but perhaps they die and are subsequently removed by cell-cleaning worker bees unobserved by the beekeeper.

Natural Control

Galleria are the natural host for certain viruses, bacteria, protozoa, and insects. In 1968, *Galleria* larvae in United States Department of Agriculture apiaries at Baton Rouge, Louisiana, were found to be infected with a new strain of *Bacillus thuringiensis* Berliner (Barjac and Thompson 1970). Similarly diseased larvae have been observed sporadically at Baton Rouge since, but there is no evidence that *Bacillus thuringiensis* Berliner has significant impact on wild populations of the greater wax moth.

In Europe, a nonoccluded virus occasionally destroys fish bait cultures of *Galleria* (Vago 1968). A nuclear polyhedrosis virus and various kinds of bacteria cause problems in commercial fish bait cultures of *Galleria* in the United States (Cantwell, personal communication, 1975). The protozoan *Coelogregarina* is said to cause fatal infections of *Galleria* in Europe (Raw 1954). No microsporidians have been reported from the greater wax moth, but it is unlikely that the species is free of these common insect pathogens.

A braconid wasp, *Apanteles galleriae* Wilkinson, appears to be one of the most common of the predatory or parasitic insects associated with *Galleria mellonella* (L.) in the southern United States (Williams 1976). This larval parasite is also recorded from Asia, Africa, Europe, and South America. It is very common and seasonally abundant in southern Louisiana and has been found in every apiary checked by the author; dozens of the small, white cocoons are often seen among the debris of damaged combs from midsummer through autumn. Singh (1962) presents a brief discussion of *Apanteles galleriae* Wilkinson biology.

The red imported fire ant, *Solenopsis invicta* Buren, commonly feeds on the immature stages of *Galleria* in infested honey bee hives in southern Louisiana (Williams 1976), and in Hawaii, the bigheaded ant, *Pheidole megacephala* (Fabricius), preys on cocooned stages of the greater wax moth (Eckert and Bess 1952).

Applied control

Current wax moth control methods may be divided into two general categories: management procedures in the apiary and management of bee products removed from the colony.

Apiary management. The management procedures utilized by progressive beekeepers are presently the only means of reducing wax moth losses in outapiaries. The operator who experiences substantial losses should implement these practices:

(1) Maintain vigorous colonies with adequate food stores.

(2) Control diseases and pests that might substantially weaken colonies.

(3) Remove wax and debris from the bottom board of the hive at least once a year.

(4) Replace stock if it is unusually susceptible to wax moth attack.

Figure 7.5. The greater wax moth (*Galleria mellonella*), adult and mature larvae. (Photo by R. A. Morse)

(5) Avoid pesticide poisoning of colonies wherever possible. Unfortunately, the logistics and labor requirements of large beekeeping enterprises prevent the short-interval inspections of outapiaries (Anderson 1969) that enable the operator to fumigate or combine weak or dead units before *Galleria* larvae cause excessive damage. The environmental problems that cause much of the apiary loss by wax moths, factors such as pesticides and dearth periods, are often beyond the commercial beekeepers' management capability.

Off-colony management of honey bee products. Fumigant chemicals and temperature control are used to prevent the greater wax moth and other moth pests from damaging honey bee products, including combs, comb honey, wax, and bee-collected pollen, after their removal from the colony.

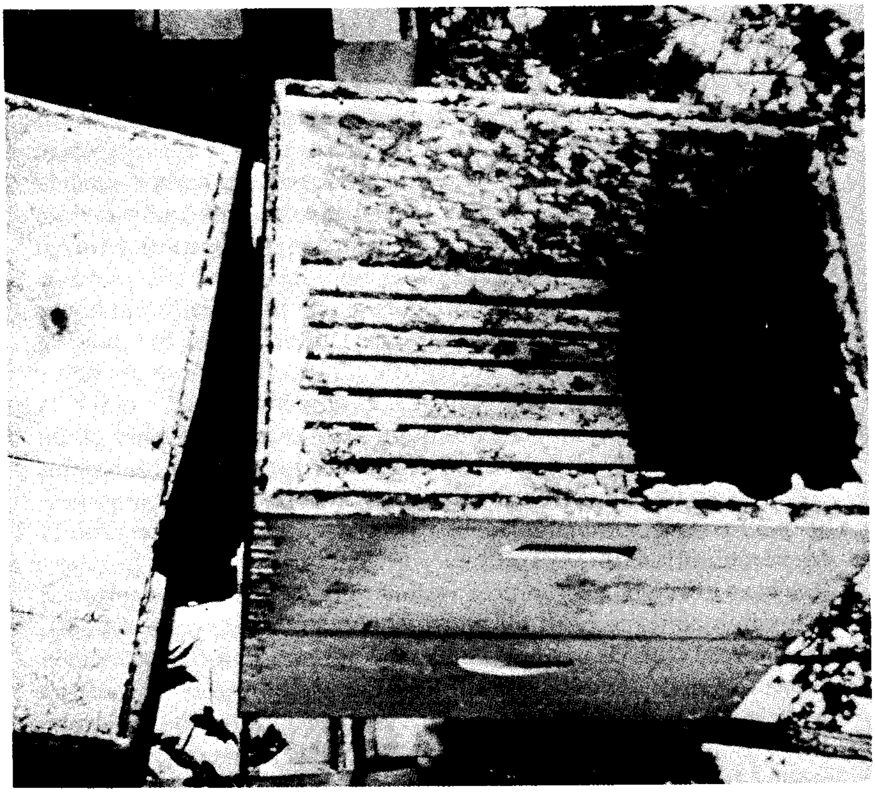

Figure 7.6. Super with thousands of cocoons of *Galleria mellonella*. Here the combs have been removed. Heavy infestations will weaken the wooden frames and supers as the larvae tunnel into the wood to spin their cocoons. (Photo by E. J. Dyce)

Chemical Control

Various insecticidal fumigants, primarily calcium cyanide, ethylene dibromide, methyl bromide, naphthalene, and paradichlorobenzene, have been used in different countries to protect honey bee products, especially combs, from moths and other insects during storage (Anonymous 1972, Lehnert and Shimanuki 1967, 1973). Fumigation has been in use to prevent comb destruction by wax moths for over two hundred years in the United States (Paddock 1930).

Lehnert and Shimanuki (1968) and Cantwell, Lehnert, and Travers (1975) demonstrated that low dosages of ethylene oxide, 36 milligrams per liter for 1.5 hours or 18 milligrams per liter for three hours, respectively, will kill all stages of the greater wax moth. Lehnert and Shimanuki (1967) reported that as little as 0.02 milliliters of ethylene dibromide (83 per cent active ingredients) per liter for 24 hours will kill all stages of *Galleria*. Paradichlorobenzene is one of the least hazardous fumigants to handle, but it is absorbed by combs of honey, and it will not kill the egg stage of moths. A modified atmosphere of 73.4 per cent carbon dioxide and 20.9 per cent nitrogen will kill all greater wax moth larvae, the most resistant stage, at 37.8° Celsius in 28 hours (Cantwell, Jay, Pearman, and Thompson 1972).

Various types and sizes of enclosures such as secondhand house trailers are used by beekeepers in the United States to fumigate and store supers of combs during the off season. Some operators fumigate combs in small rooms or chambers before storage in larger mothproof rooms. At the honey bee research facility of the University of California at Davis, chambers designed as cool rooms are used as mothtight fumigation and storage rooms. Many beekeepers simply fumigate individual stacks of supers when combs are stored in buildings during warm weather.

A very effective, economical system of outdoor comb fumigation that eliminated the need for an expensive building was developed for the cool climate of New Zealand (Paterson and Bennett 1963). Supers of empty combs or combs containing honey are stacked on a specially designed concrete base, covered tightly with black polyethylene sheet (0.127 millimeters thick), and fumigated with methyl bromide at the rate of 3.3 kilograms per 384 supers. One treatment effectively protected combs against wax moth damage until they were returned to use the following season.[1]

Nonchemical Control

Exposure of beekeeping equipment or harvested honey bee products to temperatures above or below the range tolerated by *Galleria* is a safe, relatively rapid method of eliminating or preventing infestations. Temperature manipulation, like carbon dioxide fumigation, eliminates the hazard of contamination of bee products with chemical residues. If artificial cold is used, the following minimum treatments are required to kill all stages of the greater wax moth: −6.7° Celsius for 4.5 hours, −12.2° Celsius for three hours and −15.0° Celsius for two hours (Cantwell and Smith 1970). (Bulky materials—containers of beecollected pollen, combs

1. Comb storage under sheets of black polyethylene in direct sunlight is not possible in warmer climates. Temperatures above 49° Celsius will destroy wax combs.

containing honey, etc.—may require considerably extended exposure times to reach killing temperatures.)

Good sanitation practices may help the beekeeper to alleviate wax moth damage. In fact, a number of commercial beekeepers have reported to the author that their losses dropped appreciably after better sanitation procedures were followed. Many hundreds of small *Galleria* larvae are often present in the frass and scraps of comb remaining after hives of comb are destroyed during warm weather. Therefore, all infested materials should be treated to kill the various stages of the greater wax moth present and prevent the buildup of wax moth populations.

Control in Comb Honey

Producers and packers of comb honey risk losing a valuable commodity if it is not protected constantly from the greater wax moth and certain other moth pests (Cantwell and Smith 1970, LeMaistre 1934). Large quantities of comb honey may be quickly rendered unsalable if warm temperatures prevail in the beekeeper's storage house, thereby accelerating moth activity and development (Roberts and Smaelli 1958, Stephen 1957).

Infestations by *Galleria* and other moths must be prevented from the time comb honey is removed from colonies until it is packaged, inasmuch as a single larva can destroy its market value. Indeed, LeMaistre's report (1934) that practically all of the beekeepers in southwestern Ontario had *Galleria* larvae in their stores of comb honey indicates that suitable precautions should be taken to protect comb honey from wax moth damage even in northern climates. A large-scale carbon dioxide fumigation procedure has recently been developed (Cantwell, Jay, Pearman, and Thompson 1972, and Jay, Cantwell, Pearman, and Thompson 1972) and is now being used at the Waycross plant of the Sioux Bee Honey Association. Included are a gasification system consisting of a 3.628-metric ton liquid carbon dioxide holding vessel, vaporizers, automatic application controls, and three large treatment rooms. Each room holds 7,000 supers of comb honey arranged in stacks 3.66 meters high. All of the supers are palletized (40 per pallet) to reduce handling and help prevent damage to the fragile combs. The original atmosphere is purged through vent tubes near the ceiling while the heavier-than-air carbon dioxide gradually fills the room. A five-day treatment period follows during which carbon dioxide concentrations inside the room are monitored constantly and an atmosphere of 80 per cent carbon dioxide is maintained automatically. Supers of honey thus treated and stored remain free of wax worms (*Galleria* larvae) for two months or longer and are removed from the treatment room as honey is required for packing.

In 1974 and 1975, the cost of controlling wax moths in one room for ten months (three treatments of 11,818.2 kilograms of carbon dioxide each) was 0.91 to 1.14 cents per kilogram of honey for each treatment. Over 680,000 kilograms of gallberry comb honey have been fumigated with carbon dioxide at the Sioux Bee packing plant during the three years (1973–1975) this method control has been used.

Queen-rearing Materials

Honey bee breeders have occasionally contaminated stocks of rendered beeswax or queen-rearing supplies made of beeswax, such as queen cell cups, with insecticides or other chemicals and subsequently have experienced great difficulties in queen production. Storage or periodical treatment in a home freezer is a satisfactory method of protecting wax to be used in queen rearing from moth damage; freezing also eliminates the need to use chemicals that might contaminate the wax.

Future Techniques

Much of the research concerned with the development of control techniques for the greater wax moth and other moth pests of honey bee colonies utilizing biological agents has been concentrated on the spore-forming bacterium, *Bacillus thuringiensis* Berliner (Ali, Abdellatif, Bakry, and El-Sawaf 1973, Bailey 1971b). Honey bee colonies dusted with a large quantity of a commercial preparation of this bacterium were unaffected (Wilson 1962); *Bacillus thuringiensis* Berliner and its toxins have no adverse effects on treated honey bees at dosages likely to be encountered in the field (Cantwell, Jay, Pearman, and Thompson 1972). Also, various strains of *Bacillus thuringiensis* Berliner have been used to impregnate wax foundation for wax moth control.

However, two major obstacles preclude the commercial application of *Bacillus thuringiensis* Berliner for wax moth control. Combs that colonies build from the spore-treated foundation are mothproof for only one season (Burges 1966, Burges and Bailey 1968, Johansen 1962), and methods so far devised for applying spore formulations to combs on or off colonies are economically prohibitive from a labor cost standpoint.

Effective control of *Galleria* was obtained when hives containing pollen were artificially contaminated with *Galleria* nonoccluded virus (Giauffret 1966), but there are questions of human safety relative to the virus. Bailey (1966) obtained good control of the greater wax moth in the laboratory with combs containing *Galleria*-specific nuclear polyhedrosis virus.

In spite of the perennial threat the greater wax moth poses to beekeeping operations in warm climates, there has been little effort to develop methods specifically designed to control it in outapiaries where most comb losses occur. Given the rapid advances in pest management during the past ten years, it is reasonable to assume that an economical, highly efficient control technique could be developed if additional research were undertaken. Indeed, results of studies at Baton Rouge, Louisiana, indicated that it may be possible and quite economical to suppress natural *Galleria* populations with moths possessing radiation-induced mutations (Nielsen 1971).

Driedfruit Moth

Eastern and western races of *Vitula edmandsae* Packard are recognized by Heinrich (1956). The western form (*Vitula edmandsae serratilineella* Ragonot) has the common name of driedfruit moth,[2] but the eastern form is designated only by the scientific name *Vitula edmandsae edmandsae* (Packard). In the western United States, the driedfruit moth is next in importance after the greater wax moth in terms of damage to stored combs.

Distribution

The driedfruit moth has been reported from nearly all of the Rocky Mountain States of the United States and from western Canada (Cockle 1920, Okumura 1966); it has been introduced into Europe also (Tiedemann 1958).

Biology

The mottled gray moths, about 20 millimeters long, are attracted to black lights (Okumura 1966; Simmons and Nelson 1975). Development from egg to adult requires about 88 days in the summertime. The species overwinters in the larval stage. Observers often confuse larvae of the Indian meal moth and the Mediterranean flour moth with mature larvae of the driedfruit moth because

2. Official common names are designated for some insects by the Committee on Common Names of Insects of the Entomological Society of America.

all are similar in size (about 15 millimeters long) and color (either white or light pink). A taxonomic key is available for identification of moth larvae that infest honey bee combs (Okumura 1966).

Besides eating a wide variety of dried fruits, the larvae feed rather commonly on pollen and honey in unprotected stored combs, tunneling through the cell walls in the process. Occasionally, they also feed on these two materials in the combs of active colonies (Cockle 1920, Okumura 1966). Grant (1976) reared this species on one of the beeswax-free diets used for the greater wax moth.

Large numbers of driedfruit moth larvae can complete their development on combs without destroying the midrib or the entire comb, which is not the case with *Galleria mellonella* (L.). Driedfruit moth larvae form a dense mass of silk webbing over the comb face (Okumura 1966, Wilson and Brewer 1974).

The driedfruit moth has also been recorded from nests of bumble bees, carpenter bees, and alfalfa leafcutter bees (Bohart 1972, Free and Butler 1959, Linsley 1943).

Some authors refer to the eastern race, *Vitula edmandsae* (Packard), as the bumble bee wax moth (Weatherston and Percy 1968) because it has been reported as a common resident of *Bombus* nests in the eastern United States (Milum 1940b, 1953). However, such a designation is inappropriate inasmuch as there is no evidence that *Vitula edmandsae* (Packard) feeds on beeswax (Okumura 1966). In accordance with European literature, the common name of the bumble bee wax moth should be restricted to *Aphomia sociella* (L.). The driedfruit moth was formerly a limited pest of comb honey (Anonymous 1932).

Lesser Wax Moth

The lesser wax moth, *Achroia grisella* Fabricius, has a scattered distribution throughout the temperate and tropical climates of the world (Hassanein, Ibrahim, el-Banby, and el-Arousy 1969, Singh 1962, Smith 1953); it occurs in most, if not all, of the United States (Eckert and Bess 1952, Vansell 1936). Generally of minor importance to the beekeepers, this species, however, is capable of destroying neglected or inadequately protected combs (Milum 1940b).

Biology

Lesser wax moths are easily distinguished from greater wax moths by their appearance and behavior even when the latter are much reduced in size as a result of inferior diet. Adult *Achroia* *grisella* (Fabricius) are small, slender-bodied, and silver-gray to buff colored with a conspicuously yellow head. Adult males reach a maximum length of about 10 millimeters, whereas the female moths are usually slightly larger, or about 13 millimeters maximum (Kunike 1930). Lesser wax moths weigh only about one-sixth to one-tenth as much as greater wax moths. The average weights of adult *Achroia* reared on a diet of dark combs containing fresh pollen were as follows: males, 11.3 milligrams (range: 3.0 to 17.5); females, 20.3 milligrams (range: 9.9 to 33.8).[3]

If disturbed, the moths run very rapidly across combs and throughout the hive for 30 seconds or more. If lesser wax moths are on a comb when it is removed from the hive, they often run to one edge of the comb and quickly fly down to the ground among vegetation. Whenever considerable numbers of adults are present, many males can be observed rapidly fanning their wings to spread the male sex pheromone that induces females to mate (Dahm, Meyer, Finn, Reinhold, and Röller 1971).

An average of 250 to 300 eggs is produced during the seven-day lifespan of the female moth (Kunike 1930).

The larvae are white and narrow bodied, have a brown head and pronotal shield, and reach a maximum length of about 20 millimeters (Milum 1940a). Each larva tends to live segregated in a silken tunnel covered with frass while growing, whereas maturing *Galleria* larvae tend to congregate (Singh 1962).

Studies by Hassanein, Ibrahim, el-Banby, and el-Arousy (1969) indicate that the optimum natural diet of *Achroia grisella* (Fabricius) larvae is dark comb containing either pollen or brood. However, larvae are most often found on the bottom board among debris, in partially rendered cakes of beeswax and in debris remaining from combs destroyed by *Galleria mellonella* (L.) larvae; they also develop in slumgum, foundation, and bee-collected pollen (Milum 1940a, Paddock 1930, Vansell 1936). Thriving colonies of *Achroia* are found only in very weak honey bee colonies.

Larvae of the lesser and greater wax moths frequently infest beekeeping materials simultaneously, but apparently *Achroia* are unable to compete if the *Galleria* larvae become numerous. For example, several thousand *Achroia* larvae and pupae in two artificial cultures maintained by the author were eaten by *Galleria mellonella* (L.) larvae upon accidental infestation.

The author has reared *Achroia grisella* (Fabricius) for over ten

3. Author's original data representing 100 adults of each sex less than 24 hours old.

generations on the beeswax-free diet developed for the greater wax moth by Dutky, Thompson, and Cantwell (1962).

Certain natural enemies of the greater wax moth, including non-occluded and polyhedrosis viruses and the wasp *Apanteles galleriae,* also attack the lesser wax moth (Bailey 1966, Rau 1946).

Bald Brood

Single cells or patches of honey bee brood that have the cells uncapped so as to expose the heads of live, apparently normal, pupae are referred to as bald brood. Worker bees chew away the remainder of the cell caps after small wax moth larvae have perforated the outer cell and the cappings, thereby exposing the developing pupae. A few malformed adult bees result from the honey bee pupae that have had fecal pellets deposited on them by the lesser wax moth larvae in these cells (Bailey 1963a). In Europe, bald brood is usually caused by the lesser wax moth, infrequently by the greater wax moth (Bailey 1963a, Milne 1942). Bald brood probably is uncommon in the United States, though it has been observed over widely separated areas.

Occasional colonies in Europe do not cap their brood normally, but either turn the cell edges slightly inward or leave a small hole in the center of the capping (Anonymous 1959). Requeening the affected colonies eliminated the condition in the latter case.

Bumble Bee Wax Moth

The bumble bee wax moth, *Aphomia sociella* L., is an unusual pest of honey bee colonies (Toumanoff 1939) that occurs in Europe and Asia. In some European countries it is common in the nests of various species of *Bombus* (Free and Butler 1959, Pouvreau 1967).

Biology

Adult *Aphomia sociella* L. are heavy bodied, similar to but slightly smaller than, greater wax moths. The body and forewing are reddish brown; females have a prominent dark spot on each forewing (Milum 1940a). Mature larvae are pale yellow in body color and reach a length of about 22 to 30 millimeters. Larvae of *Aphomia sociella* L., like those of the greater and lesser wax moths, construct dense tunnels of silk in which they feed. According to Pouvreau (1967, 1973), the larvae readily consume brood (eggs, larvae, and pupae), as well as pollen and honey stored in the wax cells within bumble bee nests, and they frequently cause the adult bees to desert the colony. The moths are attracted to the odors of active bumble bee colonies.

Indian Meal Moth

The Indian meal moth, *Plodia interpunctella* (Hubner), is one of the worst moth pests of whole grains and cereal products. In addition, the larvae feed on a wide variety of other food materials including dried fruits, dried milk, candy, dried roots, herbs, nuts, seeds, dead insects, and bee-collected pollen (Metcalf, Flint, and Metcalf 1962). As previously mentioned, it is particularly common in unprotected bee-collected pollen. The species is a minor pest of nests of alfalfa leafcutter bees, *Megachile pacifica* (Fabricius) (Bohart 1962). It also occurs in the nests of bumble bees (*Bombus*), mining bees (*Anthophora* and *Osmia*), and paper wasps (*Polistes*) (Linsley 1943, Rau 1946).

Distribution

This moth has spread throughout the world from its European origin (Metcalf, Flint, and Metcalf 1962).

Biology

The attractively marked small moths are up to nine millimeters long; basally the forewing is a grayish color and the remaining half to two-thirds, as well as the head and thorax, are reddish brown with darker markings, which gives the moth a banded appearance (Silacek and Miller 1972; Simmons and Nelson 1975). At rest the moth holds its wings narrowly together along the body line (Metcalf, Flint, and Metcalf 1962). At maturity, the brown-headed larvae average about 13 millimeters in length and are usually dirty white, but their body color varies to pinkish or greenish (Hamlin, Reed, and Phillips 1931). In warm climates, Indian meal moth larvae develop on pollen and cocoons or dead brood in stored combs (Dunham 1929, Eckert and Shaw 1960), combs containing clusters of dead bees, accumulations of dead bees (Eckert and Bess 1952, Gilbert 1939, Wilson and Brewer 1974), or debris from these materials. An advanced infestation can be identified by the loose, flimsy webbing that is constructed by larvae across the face of combs. Fortunately, it does not feed on the beeswax of combs or processed wax. The life cycle may be completed in four to six weeks in summer or in heated buildings.

Mediterranean Flour Moth

Milled cereal products are often damaged by the Mediterranean flour moth, *Anagasta kuehniella* (Zeller), although whole grain is also attacked. Before the development of modern fumigation techniques, it was considered the most serious insect pest of flour mills in the United States.

Distribution

The Mediterranean flour moth occurs generally throughout the world (Metcalf, Flint, and Metcalf 1962).

Biology

Stored honey combs containing pollen are sometimes infested; but this moth cannot develop on empty brood combs or dead insects (Eckert and Bess 1952, Essig 1940, Milum 1940a). *Anagasta kuehniella* (Zeller) is an occasional resident of bumble bee nests (Essig 1940, Milum 1940b). The pale gray moths are about 6 to 13 millimeters long with two dark zigzag markings on the forewings. Upon hatching, larvae begin to spin small silken tubes in which they live and feed. Flimsy cocoons are constructed by mature larvae within the food material, their webbing, or nearby cracks and crevices.

Death's Head Moths

Honey bee colonies in some regions of the world are subject to occasional predation by unique sap, nectar, and honey feeding hawk moths (Sphingidae) of the genus *Acherontia*. Their common name is derived from the pattern on the dorsum of the thorax which resembles a death's head design.

Distribution

Acherontia atropos (L.) is indigenous to parts of Europe and Africa (Büdel and Herold 1960, Brugger 1946, Lundie 1952, Smith 1960). Other species of *Acherontia* frequent honey bee colonies in Asia (Smith 1953, Singh 1962).

Biology

A medium-sized, heavy-bodied moth, *Acherontia atropos* (L.) has dark gray forewings and yellow hindwings with two heavy dark bands toward the apex. Moths of this species can produce a whistling sound by expelling air from the pharynx. Though the adults feed mainly on sap from tree wounds, they may resort to robbing nectar and honey from the hives of honey bees (Brugger 1946), taking a teaspoonful or so from open cells with each visit. Nightly attacks may cause the bees to become agitated and remain so during the daytime. The cadavers sometimes found in hives indicate that these moths are not always successful thieves (Brugger 1946).

Moths in Bee-Collected Pollen

Recently, commercial-scale harvesting of pollen collected by honey bees has received considerable attention in many countries, principally to supply the pharmacy, health food, and beekeeping (pollen supplement) markets (Anonymous 1975, 1976b). Pollen trapped from honey bee colonies must be handled properly to prevent deterioration or complete destruction by fermentation, molds, and heat, as well as attack by a variety of pollen feeding insects including moths (Woodrow 1948).

At Baton Rouge, Louisiana, the Indian meal moth commonly infests spilled or residual bee-collected pollen. The driedfruit moth or other moth species can be expected to attack unprotected bee-collected pollen in other geographical areas. Beekeepers who collect large volumes of pollen, particularly those located in warm climates, should practice strict sanitation in order to prevent the buildup of pollen-infesting insects that could attack their stored combs.

Cold storage at subfreezing temperatures in airtight containers is probably the best method of protecting large quantities of pollen against deterioration and insect attack. (Freezer storage requires nearly 1,440 cubic centimeters of space per kilogram of pollen.) Pollen intended for beekeeping use may also be dried and stored in airtight containers or it may be mixed with expeller-type soybean flour (1:1) and then stored at room temperatures (Whitefoot and Detroy 1968).

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