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ABSTRACT

This study addresses the problems caused by the major insect and rodent pests and molds and mildews in libraries and archives; the damage they do to collections; and techniques for their prevention and control. Guidelines are also provided for the development and initiation of an Integrated Pest Management program for facilities housing library and archival materials. Topics discussed include the following: (1) perspectives on pest management in libraries and archives; (2) hazards of these pests; (3) health concerns arising from pesticide use in buildings; (4) management responsibility for an effective, safe program; (5) the habits and life histories of the major pests (i.e., silverfish, firebrats, "bookworms," cockroaches, psocids or booklice, carpet beetles, clothes moths, termites, mice, rats, molds and mildew); (6) recognition of damage caused by each of these pests; (7) management and control of the pests; (8) the application of integrated pest management to library and archive situations; and (9) surveillance of the program. Final observations on costs and benefits conclude the report, and the 30 illustrations included in the narrative are listed. (27 references) (CGD)

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Study on integrated pest management for libraries and archives

General Information Programme and UNISIST

United Nations Educational,
Scientific and Cultural Organization

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Study on integrated pest management for libraries and archives

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PREFACE

In order to assist in meeting the needs of Member States, particularly developing countries, in the specialized areas of Archives Administration and Records Management, the Division of the General Information Programme has developed a long-term Records and Archives Management Programme - RAMP.

The basic elements of RAMP reflect and contribute to the overall themes of the General Information Programme. RAMP thus includes projects, studies and other activities intented to :

- develop standards, rules, methods and other normative tools for the processing and transfer of specialized information and the creation of compatible information systems ;

- enable developing countries to set up their own data bases and to have access to those now in existence throughout the world, so as to increase the exchange and flow of information through the application of modern technologies ;

- promote the development of specialized regional information networks ;

- contribute to the harmonious development of compatible international information services and systems ;

- set up national information systems and improve the various components of these systems ;

- formulate development policies and plans in this field ;

- train information specialists and users and develop the national and regional potential for education and training in the information sciences, library science and archives administration.

This study, prepared, under contract with IFLA International Office for Preservation and Conservation, Library of Congress, by Thomas A. Parker, Phd, Pest Control Services, Inc., deals with the problems of pests of libraries and archives on their habits and life histories, on methods for recognition of damage which they cause, and on the best way to handle the management for treating library and archival pests.

A part of the study concerns the application of integrated pest management to library, archival and collection pest problems the supervision of the programme and final observations on costs and benefits.

In this study many illustrations complement the author's text ; a list of these illustrations as well as a bibliography complete this important study.

Comments and suggestions regarding the study are welcomed and should be addressed to the Division of the General Information Programme, UNESCO, 7, Place de Fontenoy, 75700 Paris, France. Other studies prepared as part of the RAMP programme may also be obtained at the same address.

INTEGRATED PEST MANAGEMENT FOR LIBRARIES AND ARCHIVES

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INTEGRATED PEST MANAGEMENT FOR LIBRARIES AND ARCHIVES

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INTRODUCTION

PURPOSE OF THE STUDY

This study has been prepared for the National Preservation Program Office of the Library of Congress, Washington, DC, under contract with the International Federation of Library Associations and Institutions (IFLA, The Hague, Netherlands) and sponsored by The United Nations Educational, Scientific and Cultural Organization (UNESCO, Paris, France) in response to the need for a better understanding of the pest problems associated with library materials and archives. Topics reviewed will be the major pests of libraries and archives, the damage they do to collections, and chniques for their prevention and control; and the development and initiation of an Integrated Pest Management program for facilities housing library and archival materials.

PERSPECTIVES ON PEST MANAGEMENT IN LIBRARIES AND ARCHIVES

The library community is concerned with insects, mold, and other pests in library and archival materials for several reasons. First and foremost among these is the commitment to preserve the collections for continued future use by mankind. Insects and mold can reduce the printed word to excrement; obliterate page after page with staining and fungal destruction; and destroy bindings, covers, and valuable documents.

The second concern is the economic loss caused by insects and mold. Insect attack can be so intense that a bindery cannot keep pace with the damage caused by beetle larvae feeding on the glue and other constituents of bindings. Mold can create great economic loss to collections in a short time, particularly in situations where water pipes burst and flood the collections, a fire results in heavy water damage, faulty air-handling systems generate high humidities, or naturally occurring floods create conditions conducive to extensive mold growth. Economic losses are created not only by the direct replacement costs of books and materials, but also by expenditures required to salvage, conserve, and restore the materials damaged by the mold growth brought on by such catastrophies.

A third consideration is the psychological revulsion of the staff and public to pests in a facility. Mice,

cockroaches, and other insects generate fear and anxiety in the minds of many individuals. People simply do not want to work in or visit an infested facility. In many parts of the world human beings have come to expect a pest-free environment.

A final consideration is concern with regulatory action by various health and sanitation agencies. Some pests present a threat only to the library collections; others, however, ay be of significance to the public health. Rodent and cockroach infestations are of particular concern to such agencies because of their potential for disease transmission to people.

HAZARDS OF PESTS IN LIBRARIES AND ARCHIVES

Not only do pests cause damage to collections and the structures that house them, but they may also have a significant adverse effect on humans. Wherever people are exposed to rodents, insects, or mold, the potential exists for bites, contact with feces and urine, food contamination, exposure to infectious agents, and allergic responses. In addition, ectoparasites of rodents have the potential of biting man and transmitting disease. Entomophobia, the fear of insects, may also be of concern when dealing with staff and the public.

The feces and urine of rats and mice, if deposited in places where they may come into contact with people or

contaminate human food and water, may transmit various kinds of infectious agents. Various fungal organisms grow in environments contaminated by pigeon and starling feces, and the airborne spores are known to cause infection in several hundred people each year (Fraser et al. 1979). Infestations of people by fleas associated with rodent infestations; of structures with cockroaches; and of collections with booklice and "paperfleas" may cause pain, discomfort, phobias, and the threat of illness.

The fine hairs of some species of carpet beetle larvae have been cited as the cause of allergic reactions in humans (Okumura 1967). Dr. Richard Brenner, of the USDA Insects Affecting Man and Animals Research Laboratory, in Gainesville, Florida, states, "We know that 8 to 25 percent of the general population, and 70 percent of the asthmatic population is allergic to cockroaches...."

HEALTH CONCERNS ARISING FROM PESTICIDE USE IN BUILDINGS

With the advent of synthetic pesticides primarily aimed at the control of pests in agricultural settings, man enthusiastically adapted many of these materials for pest control in buildings. Subsequent detection of adverse health effects from pesticides soon tempered the initial enthusiasm for sole reliance on these chemicals in a pest-management

strategy. The effects of chronic and incidental exposure, coupled with increasing pest resistance to chemicals, are a major concern worldwide.

Since the 1960's, when organo-chlorine pesticides were replaced by faster acting but more toxic organo-phospate and carbamate insecticides, over-exposure has resulted in an undetermined number of cases of systemic poisonings (Davies 1977). The effect of these pesticides on human beings can be seen most clearly in those parts of the world where knowledge of safety precautions has not kept pace with the chemical technology (Davies et al. 1978). Problems arise during handling and mixing of the chemical concentrates, and also during application where subsequent formation of surface deposits result from airborne concentrations.

When an insecticide is sprayed on a surface indoors, the solvents and small amounts of insecticide are volatilized into the space occupied by the collections and human beings. These chemical concentrations, although of low levels, may redeposit on surfaces far from the site of initial application. Small amounts of chemicals may also be inhaled by individuals and may cause adverse reactions. The more volatile an insecticide, the more chemical will be released into the air. Depending on the type of application, these airborne amounts will subside after a period of hours or days, and eventually

the insecticide itself will be broken down into nontoxic elements by the action of moisture in the air and ultraviolet light. The medical significance of chronic and incidental exposure has become as great as that of acute exposure (National Academy Press 1980).

Concern about the effects of pesticide exposure on human health was first expressed in relation to agricultural uses. It is now presumed, however, that significant exposure is also occurring in the urban setting, where the population at risk is not only different, but also much larger. In addition, the chemicals used by urban residents are often different from those used in agriculture, and misuse is frequent. Unfortunately, health concerns about pesticide use in urban areas are based largely on effects documented in agricultural situations, and few if any comprehensive studies of the effects in urban areas have been initiated (National Academy Press 1980).

Chemical pollutants in libraries and archives are of prime concern, particularly where insecticidal sprays and toxic fumigants are being used as a means of controlling insect pests and mold. The move to build more energy-efficient buildings as a result of increasing energy costs has heightened the awareness of many people to the dangers of chemical pollutants in indoor environments.

MANAGEMENT RESPONSIBILITY FOR AN EFFECTIVE, SAFE PROGRAM

Management must realize that no simple solutions exist to the problem of achieving maximum prevention and control of pests in library and archival collections with minimum risk to the collections, staff, and the public. A combination of techniques is usually required to maximize the effectiveness of any pest control program. The term "Integrated Pest Management" (IPM) has been coined to embody the concept that all pest control programs must rely on several approaches working in concert to effect the desired result. To design an effective and safe program for a facility, management must consider an IPM approach.

Libraries and archives, where books, printed materials, manuscripts, maps, prints, photographs, and various other materials are stored, perused, and exhibited, are not unlike the setting in agriculture where huge quantities of foodstuffs are stored for long periods of time. The library setting is a concentration of foodstuffs, including starches, cellulose, and proteins, which form a banquet for insects, rodents, and mold. This environment creates many opportunities for nesting sites for pests that do not feed directly on the collections. The environment in which these foodstuffs are stored is indoors, protected from extremes of harsh climates. Populations of pests specific to this microenvironment can

easily explode and cause serious damage if IPM approaches are not fully utilized to prevent this from happening.

Chemical solutions to pest problems must be considered an alternative of last resort. When working with pesticides, management must be aware of the laws and regulations governing their use and the legal liability and potential consequences their use entails. Short- and long-term exposure of humans to pesticides may return to haunt management in the form of law suits stemming from actual or perceived illness.

Management is responsible for designing an IPM program that should comprise the following five key actions (Baur 1984):

1. Establish an inspection or surveillance program or system for the facility that will yield prompt awareness of a possible problem.

2. Determine the extent and nature of the possible problem, that is, the pest species, their density, and location.

3. Devise an Integrated Pest Management plan for prevention, control, or elimination of the problem.

4. Oversee the implementation of the devised plan and be willing to modify it as indicated.

5. Monitor the results of the effort.

MAJOR PESTS OF LIBRARIES AND ARCHIVES: THEIR HABITS AND LIFE HISTORIES

Many persons have recognized and written about insects injurious to books and library materials through the centuries. Aristotle, 2200 years ago, wrote: "In books also animalcules are found, some resembling the grubs found in garments, and some resembling tailless scorpions, but very small." His "tailless scorpion" was probably the book scorpion, Chelifer cancroides. In fact, as of 1922, it was estimated that over 800 references to the subject had been made in the literature, including 33 by poets (Reinicke 1922).

In 1936 Weiss and Carruthers listed 439 references in their bibliography of the literature concerning the more important insect enemies of books. Since that time, hundreds of articles have appeared on topics ranging from the use of anti-feedants (Zaitseva 1987) to protection programs for book collections (Dvoriashana 1987). Obviously interest is keen

with respect to the prevention and control of biodegradation of library materials.

Damage to library and archival materials is directly caused by rodents, insects, and mold. Indirect pressures on collections may be brought about by nesting from vertebrates and birds. Damage from insects to these materials results when insects use them as a food source. Both immature and adult stages of cockroaches, silverfish, various beetles, termites, fabric pests, and booklice may cause feeding damage to library materials.

In the case of beetles, the larval stage is primarily responsible for the feeding damage. The larvae chew their way through a book, immediately inside the cover and spine, ingest the material, and leave a tunnel filled with powdered excrement (frass). Once the larvae have completed their development, they pupate and the adult beetles emerge by chewing their way out. Small round exit holes are left in the book.

In this section we will discuss the more important pests of library and archival materials. Species of insects may differ around the world, but their habits, life histories, and damage generally can be recognized and summarized regardless of minor differences in speciation.

SILVERFISH AND FIREBRATS

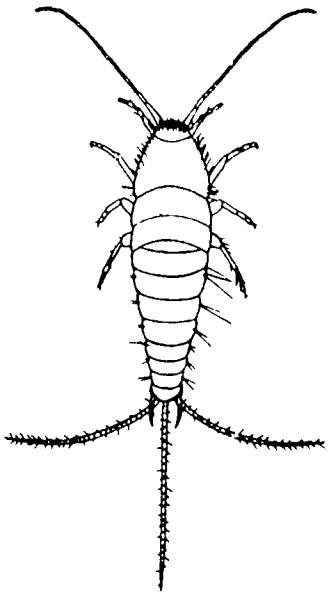


FIGURE 1. - A silverfish, Lepisma saccharina L. This species is one of the most common indoor pests of library materials. (Courtesy of Kingsolver and Pest Control in Museums)

Silverfish (Figure 1) are one of the most common pests of libraries and structures. They tend to feed on products high in carbohydrates (starch) and proteins. Such materials as paper, paper sizing, prints, glue and paste, wallpaper, and drywall are favorites of silverfish. They have also been known to feed on fabrics made from plant fibers such as linen, rayon, lisle, and cotton, particularly starched linen or cotton. They sometimes infest flour and other cereal products.

Silverfish are among the most primitive of all insects and exhibit growth without a distinct metamorphosis. They are carrot-shaped in form, long and slender, broad at the fore end, and gradually tapering to the rear. Superficially they have a fish-like appearance and hence the name silverfish, or "fishmoths." They have short legs, long antennae, and tail-like appendages at the end of their body, sometimes giving them the name "bristletails." They are wingless and generally covered with scales. Some are silver in color, whereas others are mottled dark and light. The young are similar in appearance to the adults except for size. They are long-lived insects, capable of living for several years. Unlike most insects, silverfish continue to molt and grow after reaching adulthood. They generally hide in dark areas and avoid contact with direct sunlight. Thus in inhabited spaces they are generally nocturnal in habit.

Silverfish roam widely looking for food, but once they have located a suitable source, they remain close to it. They are pests of paper, particularly paper that has a glaze upon it. They are especially fond of the sizing in paper, which may consist of starch, dextrin, casein, gum, and glue (Mallis 1982). Wallpaper and wallpaper paste are commonly eaten. Heavy attacks will loosen the wallpaper, and signs of holes may appear in the paper. Often paste, sizing, and dyes are the attracting ingredients in paper products. Some silverfish

prefer onionskin and cellophane, whereas newsprint, printed or unprinted cardboard, and brown wrapping paper are not eaten. Papers of pure chemical pulp are more likely to be attacked than those consisting in part of mechanical pulp. Highly refined chemical papers are often attacked.

Of the many species of silverfish in the world, 13 are known from the United States. Some prefer cool, moist environments, others warm and moist environments. Silverfish eggs are laid singly or in twos or threes. They may be laid over several days or even weeks. The eggs of the cool, moisture-loving silverfish incubate for approximately 45 days before hatching. The young silverfish may grow to reproductive age in 3 to 4 months. Temperatures of 72° F (22° C) and above favor the development of these types of silverfish, but temperatures above 98° F (37° C) will kill the nymphal forms. Development of all stages of these types of silverfish is best at 72° to 80° F (22° to 27° C) and at a relative humidity of 75 to 97 percent. Some may live as long as 3 1/2 years under these conditions.

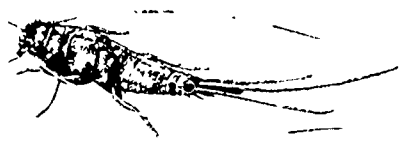


FIGURE 2. - The firebrat resembles a silverfish, but is found in warm, moist environments indoors. (Courtesy of Illinois Natural History Survey)

The firebrat (Figure 2) prefers much warmer temperatures: 90° to 106° F (32° to 40° C) is optimum. The name "firebrat" is applied to this insect because it commonly occurs in and around ovens, bakeries, boiler rooms, and other extremely warm areas. Firebrats and other members of this group are dark-loving insects and move rapidly when lights are turned on. Like silverfish, they prefer to hide in the security of cracks and crevices during the daytime.

Firebrats mature quickly to become adults in 1 1/2 to 4 1/2 months. Batches of eggs are laid in cracks and crevices. The incubation period under optimum conditions is 12 to 13 days. The firebrat may pass through from 45 to 60 instars (stages) in its lifetime (Sweetman 1938). Injured appendages on the insect are regenerated throughout life. It is difficult to determine the difference between a mature and an immature firebrat. Freezing temperatures will readily kill nymphal firebrats.

In temperate climates silverfish tend to migrate vertically depending on the season the year. In the hot months of summer they will migrate down into the cooler, more moist portions of the building, and in the fall and winter they will tend to migrate to attics and higher levels of the building. Drying out living spaces of a building with heat in the wintertime will help to reduce silverfish populations.

The heat also eliminates the microscopic mold that grows on plaster walls and drywall providing a food source for silverfish. In cool, moist basements, and commonly in poured concrete buildings, silverfish are a year-round problem.

It is impossible to eliminate bringing silverfish into a library. Silverfish are a very common problem in cardboard box and drywall manufacturing facilities. They lay eggs in the corrugations of cardboard boxes, one of their favorite areas for egg deposition. Although the adult silverfish may not feed directly on the cardboard, they very commonly feed on the glue that holds the cardboard box together. With every cardboard box coming into a library, a new load of silverfish and their eggs is bound to arrive. Upon hatching, depending on the conditions in which the box is stored, they may then roam widely to find a suitable food source.

THE "BOOKWORMS"

In the literature the term "bookworm" has been used to describe everything from silverfish and cockroaches to the larvae or grubs of beetles. Phillippus of Thessalonica early in the first century A.D. compared satirically the grammarians of that day to bookworms, thus first voicing a comparison now used so often that instinctively one thinks of a very studious person as a "bookworm." In this discussion the term bookworm

is confined to the larvae of certain species of beetles known to attack books. The grubs or larvae of certain beetles are restricted to feeding on the paste and glue of the spine and covers of bindings. Others are known to excavate the pages themselves and in fact may continue feeding from one book to the next right on the shelf.

The Cigarette Beetle. - This cosmopolitan insect feeds on drugs, leather, spices, dried vegetable matter, herbarium collections, corn husk dolls, chocolate, breakfast foods, books, and rare manuscripts. The adult beetle is cinnamon-colored, covered with golden pubescence, with its

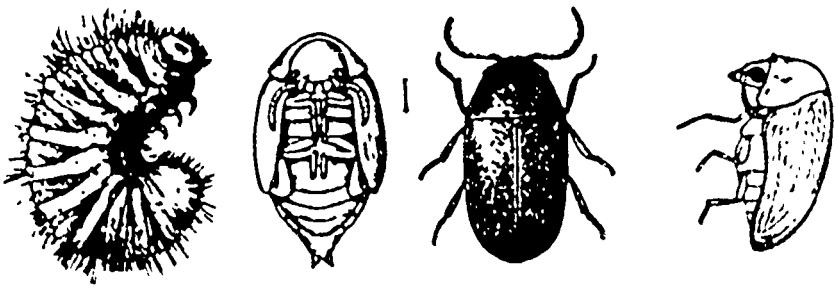


FIGURE 3. - The cigarette beetle, Lasioderma serricorne (F.) has its head tucked down at a right angle to the axis of the body. (Courtesy of Kurtz and Harris)

head tucked down at a right angle to the axis of the body (Figure 3). The larva is a small, white, hairy grub with strong mandibles (Figure 4).

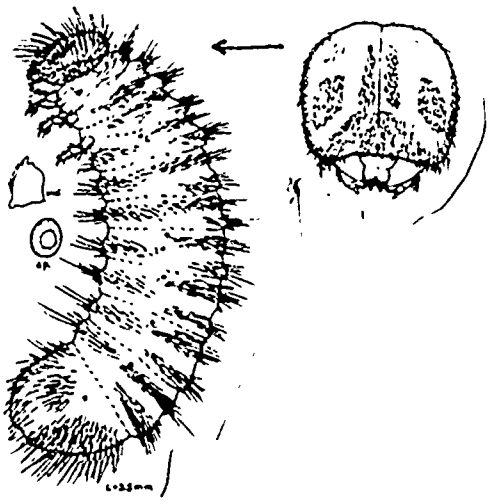


FIGURE 4. - The cigarette beetle larva or grub chews tunnels or galleries packed with excrement (frass) as it develops into an adult beetle. (Courtesy of Peterson)

Eggs are deposited near the surface of the binding or on the edges of the leaves and hatch in 5 or 6 days. The young grubs penetrate the book and tunnel their way up the spine or on the inside of the cover. After becoming full grown and before transforming to pupae, the grubs make their way close to the exterior surface. A pupal chamber is then hollowed out by the grub, and here the grub transforms into a pupa. The adult beetle emerges from the pupal chamber by chewing a small hole through the exterior of the binding. Approximately 2 months are needed for a complete life cycle from egg to adult. Four or more generations a year are not unusual, particularly in the tropics.

The Drugstore Beetle. - The drugstore beetle infests books and manuscripts and is another one of the "bookworms" (Figure 5).

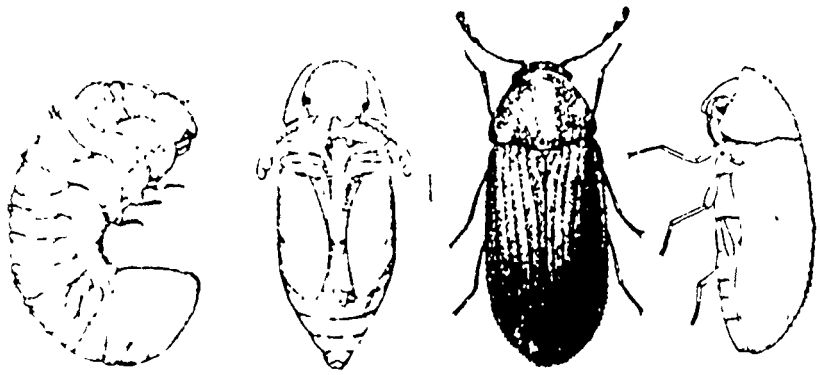


FIGURE 5. - The drugstore beetle, Stegobium paniceum (L.) is another example of a "bookworm" whose larva and adult damage books. (Courtesy of Kurtz and Harris)

Where the cigarette beetle larvae tend to confine their feeding activity to the spine and glue that holds the book together, drugstore beetle larvae often tunnel through the pages of the book, as well as emerge through the cover and spine. This type of infestation may be found in moist storage areas of libraries. Active infestations are a threat to books and should be dealt with quickly. Only those books showing small, round exit holes associated with powder drifting onto the books and shelving, should be treated. Small, round, dark exit holes from older books, particularly pre-nineteenth century books, that show no powder associated with the holes are not active infestations and nothing need to be done to them.

Eggs of the drugstore beetle are laid singly on books. The larval period ranges from 4 to 5 months (Figure 6).

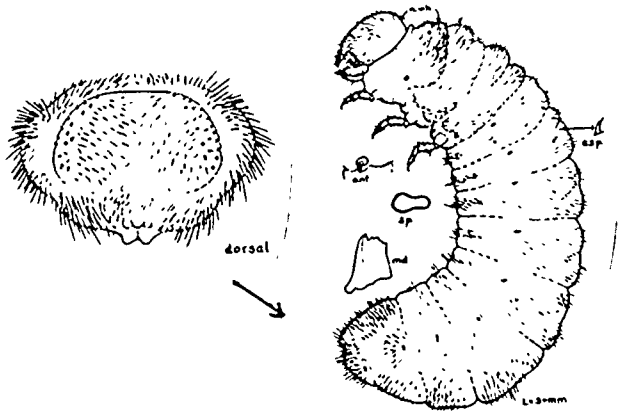


FIGURE 6. - The larva of the drugstore beetle is a grub that tunnels into bindings, covers and books. (Courtesy of Peterson)

Generally 7 months is required to complete the life cycle from egg to adult in a temperate climate. In warmer climates, 4 broods per year are possible.

<u>The Mexican Book Beetle</u>. - This dark brown, chunky beetle is covered with fine, silky hairs. The grub is about the same length as the adult and is cream colored with a shining head and dark mouth parts. It is usually found curled and C-shaped in its frass-encrusted tunnels. This species has been reported to damage books and leather, particularly in the tropics. Old volumes with handmade paper have been badly

damaged. Injury in more recent books with clay-filled, chemical-laden paper is generally restricted to the bindings. In some instances the larvae are cannibalistic, which may explain why few individuals are found in the books when compared to the extent of damage. Infestations generally start by adults laying eggs around the edges of the binding and the larvae first eating the binding paste, then the bindings.

The White-Marked Spider Beetle. - Linnaeus in 1776 mentions that this species is very injurious in libraries. In 1934 the white-marked spider beetle was found in combination with the drugstore beetle in a large library in the eastern part of the United States. It is a cosmopolitan species and is found in storerooms, cellars of houses, museums, and warehouses where it feeds upon vegetable and animal substances including flour, cottonseed, wool, furs, clothings, roots, and dried plants (Weiss and Carruthers 1936). The adult (Figure 7) is reddish brown and has chocolate colored hairs. In the female the wing covers are marked with two patches of white hairs. The larva

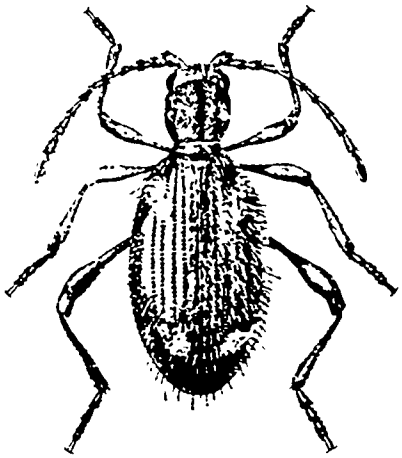


FIGURE 7. - The white-marked spider beetle, Ptinus fur (L.) is another member of the "bookworms" whose larvae chew galleries in books. (Courtesy of USDA)

is similar in appearance to the drugstore beetle larva. Its life history, activities, and damage to books is also similar. The brown spider beetle (Figure 8) has been reported

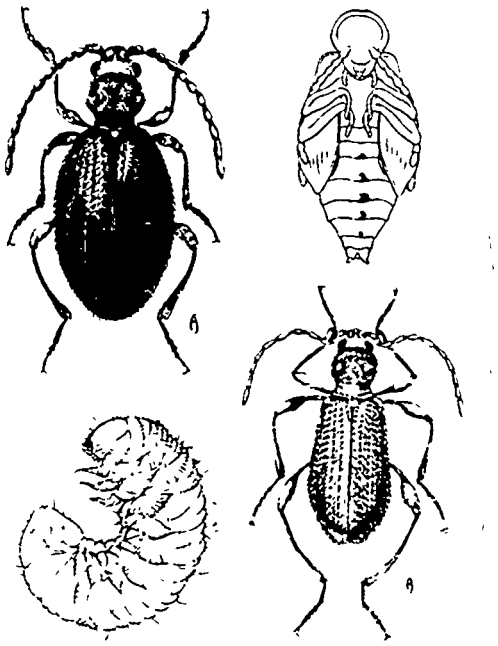


FIGURE 8. - The brown spider beetle, Ptinus clavipes Panzer larva is a "bookworm" which may damage books. (Courtesy of Mallis)

from three continents and is said to prefer books bound in leather and sheepskin. Usually its galleries are found in the leather over the spine.

COCKROACHES

Substantial damage to library materials can be attributed to various large species of cockroaches. Fecal material, streaking, and chewing damage can happen "overnight." These problems are more prevalent in subtropical and tropical areas of the world, but damage can often be found in temperate climates. Roaches are omnivorous feeders, and in some countries parchment cannot be used for legal documents because of their fondness for this material (Mallis 1982). Certain large species regurgitate a dark-colored fluid from their mouths (attar) while feeding and around their runways and hiding places.

In addition to the direct damage to library and archival materials, one must be concerned with the suspicion of cockroaches as disease carriers. Many references can be found in the literature documenting a variety of disease organisms in and on cockroaches and their fecal material. In more recent years several studies have shown that people are allergic to cockroaches, particularly to the German and American species.

Cockroaches exhibit a gradual metamorphosis. Eggs are formed in a double row encased in an egg capsule projecting from the rear of the abdomen of the female. The egg capsule is dropped and may hatch within a day or up to 2 months later

depending on the species. Nymphal cockroaches emerging from an egg capsule have no wings and crawl about seeking a food source. After developing through a series of stages (instars) the cockroach will emerge as an adult capable of reproduction.

The American Cockroach. - The American cockroach (Figure 9)

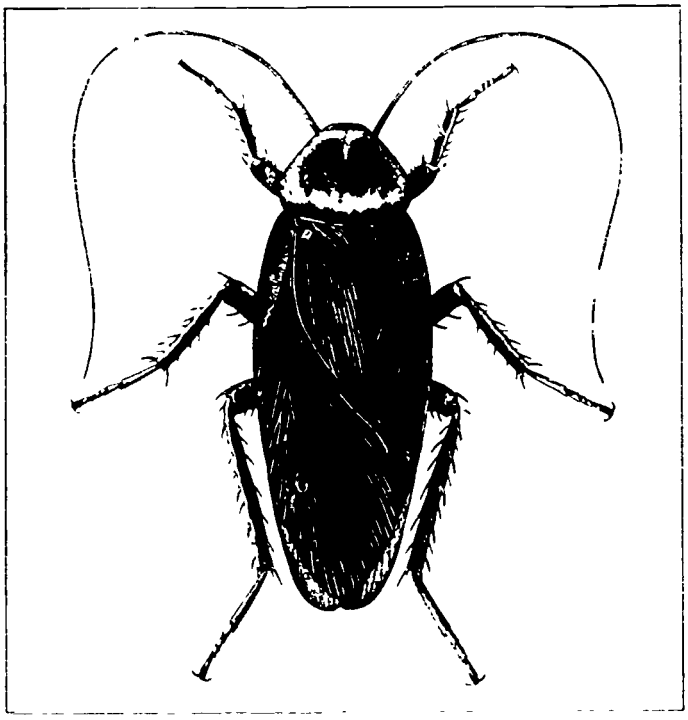


FIGURE 9. - The American cockroach, Periplaneta americana (L.) is very damaging to paper products and books, particularly in warmer areas of the world. (Courtesy of Mallis)

tends to hide in dark shaftways, basements, and false ceilings during the daytime, emerging at night to roam the library and feed on library materials. This species, 1 1/2" long, is the

largest of the structural roaches and has reddish-brown wings and light markings on the thorax. It is commonly found in warm, moist situations, such as boiler rooms, steam heat tunnels, ships, and sewer systems. This species is commonly found outdoors in subtropical and tropical areas and occasionally in temperate areas. American roaches have been found thriving under several inches of snow in smoldering refuse at an open dump in Waltham, Massachussets, when the outside air temperature was well below freezing (Mallis 1982).

The female of this species forms an egg capsule which will be dropped or sometimes glued to surfaces. In time, nymphal roaches will emerge from the egg capsule. These young roaches will then go through a series of molts until reaching adulthood, a developmental process that takes well over a year. The lifespan of this species of cockroach from egg to death can last well over 2 years. The habit of the female to glue her egg capsules to carefully selected surfaces increases the chance of libraries importing this species into the facility on deliveries. In the southern portion of the United States, American cockroaches commonly fly around street lights. In the north they exhibit a more gliding type of flight.

The Oriental Cockroach. - The oriental cockroach (Figure 10)

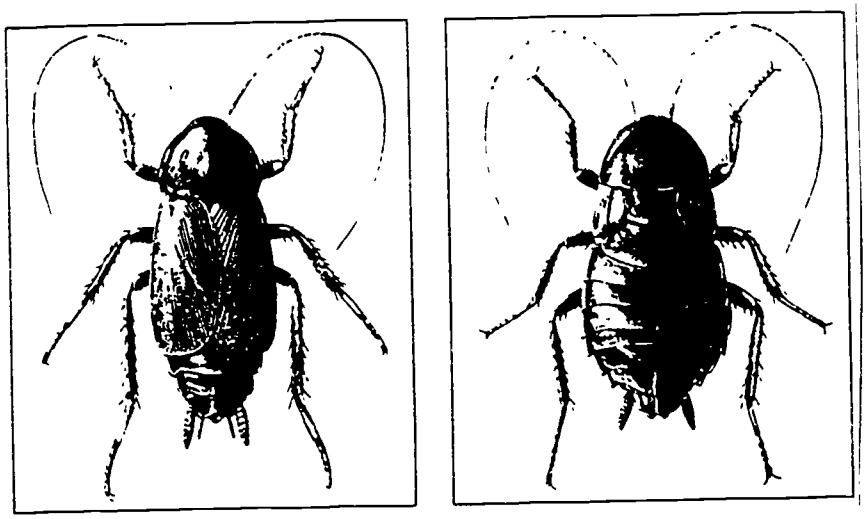


FIGURE 10. - The oriental cockroach, Blatta orientalis (L.). The male is on the left and female on the right. Note the absence of developed wings in the female. (Courtesy of Mallis)

is a dark brown to black cockroach. The male's wings do not reach beyond the tip of the abdomen, whereas the female is essentially wingless. Its damage to library materials is similar to that of the American cockroach except that the oriental roach does not produce pelletized excrement. This roach prefers to live in cool, moist places such as sewers, basements, air-conditioning systems, and areas associated with water pipes, piping, and floor drains. Where the American roach will be found roaming on many floors of a building, the oriental roach will generally be found on lower floors and

horizontal surfaces because it lacks sticky pads on its feet and cannot climb smooth, vertical surfaces. The claws on the feet of all cockroaches, however, enable them to climb rough surfaces. Like the American roach, the oriental roach is also notably gregarious. It is commonly known as the "water bug."

The oriental cockroach, which is less wary and more sluggish than the other species, is most disliked because of its habit of traveling in sewers and living on filth. In the warm months of the year or in tropical or subtropical areas, it may enter a structure under an exterior door or through air ducts or ventilators. Interior garbage-collection chutes and incinerators are frequently infested with this species.

The female may carry the brown egg capsule for 30 hours. The capsule consists of two rows of eight eggs each. The capsule is deposited in some warm, sheltered spot where food is readily available. At room temperature, incubation averages 60 days. It takes approximately 1 year for this cockroach to reach adulthood. As an adult, it will live up to 6 months.

The Australian Cockroach. - The Australian cockroach (Figure 11) closely resembles the American roach, but can be separated

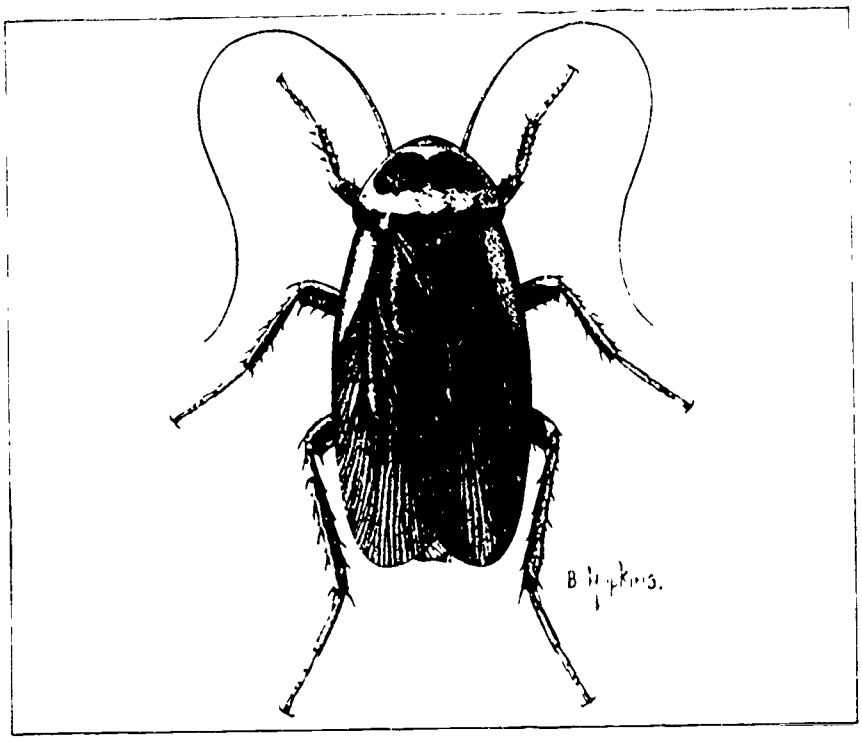


FIGURE 11. - The Australian cockroach, Periplaneta australasiae (Fabr.) has bright yellow markings which set it apart from the American cockroach. (Courtesy of Mallis)

from it by its slightly smaller size and the distinct yellow margins on the thorax and light yellow streaks on the sides at the base of the wing covers. It prefers warm, moist conditions. Although this species is commonly found in more tropical regions of the world, it has been found indoors in heated buildings as far north as Canada.

The egg capsule of this species consists of 24 eggs in two rows of 12 each. After the egg capsule is dropped it takes approximately 40 days to hatch into nymphal roaches. The nymphs take nearly 1 year to develop to adulthood. Like other large cockroaches, they will readily feed on book covers and paper products.

The German Cockroach. - The German cockroach (Figure 12) is

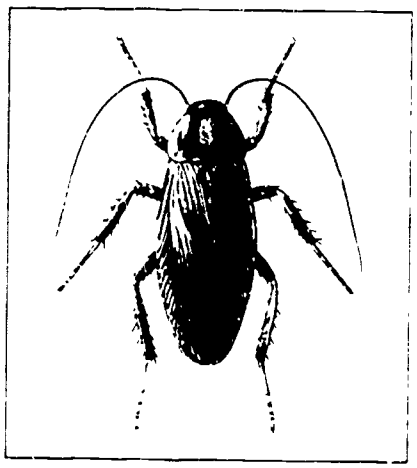


FIGURE 12. - The German cockroach, Blattella germanica (L.) is normally a pest of food handling areas and does not damage library materials. (Courtesy of Mallis)

probably the most commonly encountered indoor roach in the world. It is frequently associated with kitchens, vending areas, food-preparation areas, and catering activities. This

cockroach prefers to hide in cracks and crannies during the daytime and roam nocturnally looking for food. It is usually found near sources of moisture.

The female carries the egg capsule until hatching time. The egg capsule, which contains up to 50 eggs, subsequently splits open along a seam, and the young roaches wiggle their way out. Sometimes young roaches hatch from the egg capsule while it is still being carried by the mother. It takes approximately 3 months to reach adulthood. Each female will produce four or five capsules in her lifetime, which may exceed 200 days.

It is quite easy for a library, particularly one with an in-house dining facility or lunch room, to become infested with German roaches. Infestations may begin with egg capsules being carried in on cartons, food stuffs, and other materials. Although this species of roach usually does not damage library and archival materials, it is an obvious nuisance and harbinger of disease organisms.

PSOCIDS OR BOOKLICE

Booklice are worldwide in distribution. They are very tiny insects measuring 1 to 2 millimeters long. Most booklice infesting books and paper products have no wings. Booklice

(Figure 13) superficially resemble the lice of birds, but are

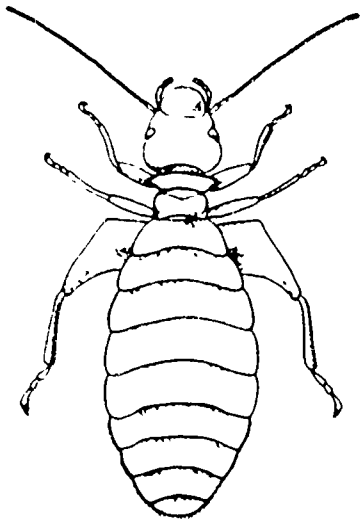


FIGURE 13. - The booklouse is a soft-bodied, tiny insect that feeds on microscopic mold which grows on library materials in damp situations. (Courtesy of Kingsolver and Pest Control in Museums)

not true lice. They may be commonly found scurrying about books and papers, especially in damp locations, as well as in warehouses, herbaria, and insect collections.

Although booklice are annoying in library materials and may damage the materials by being smashed between the pages, they usually cause negligible damage. During warmer months of the year they are most numerous in damp, warm, undisturbed situations. In temperate areas of the world, when buildings are heated in the winter, booklice populations are

dramatically reduced. The reduction of dampness by heat reduces the growth of fungi upon which booklice feed.

Psocids feed on microscopic molds. Any material of plant origin, such as furniture, paper, or books, when stored in a damp locality, is likely to support a profuse growth of these mildews, which in turn encourage infestation by psocids (Mallis 1982). They are fond of starch, starchy pastes, and glue of books and wallpaper. Sometimes people refer to these small insects as "paper fleas". Unlike true fleas, booklice do not bite humans. They are readily introduced into a building in furniture, boxes, books, and paper, all of which may have microscopic molds upon which they feed. They hide in dark areas, behind molding and baseboards, between floors and in the wall space, and behind electrical and plumbing fixtures, as well as in many of the pipe wrappings.

The most common booklouse reproduces parthenogenetically, that is, without having to have a mate. In fact, no males have been found for some of the booklice. The nymphal booklice, upon hatching from the eggs are very tiny and do not move about much. As they molt and grow, they take on a slightly grayer appearance. The life cycle averages 110 days and may be terminated by cold weather. In an environment of continuously low relative humidity, (below 35 percent) booklice will desiccate and die.

CARPET BEETLES

Carpet and hide beetles (Figure 14) belong to the family Dermestidae. The hide beetles are a special pest of hides, leather, meat, and similar animal products. They are often referred to as skin beetles, larder beetles, tallow beetles, or dermestids. Rarely are hide beetles found in library materials. The larder beetle has been recorded as occurring in great numbers among books, doing considerable damage to the covers (O'Conor 1898). One would expect, from the normal feeding habits of this beetle, that leather bindings would be particularly subject to attack.

Carpet beetles are much smaller than hide beetles and are common pests of products containing protein such as woolens, rugs, carpets, upholstered furniture, museum specimens, and similar materials. Most adult carpet beetles feed largely on pollen and nectar. The larvae are responsible for damage to certain library materials. Such beetles as the black carpet beetle, the common carpet beetle, the warehouse beetle, the furniture carpet beetle, the varied carpet beetle, and the larger cabinet beetle are most commonly found in museums, libraries, and collections.

Various protein sources provide food for the larvae of carpet beetles. They are commonly found feeding on felt used for the lining of rare book containers and exhibits; felt hats and accessories; all manner of woolen goods; tapestries;

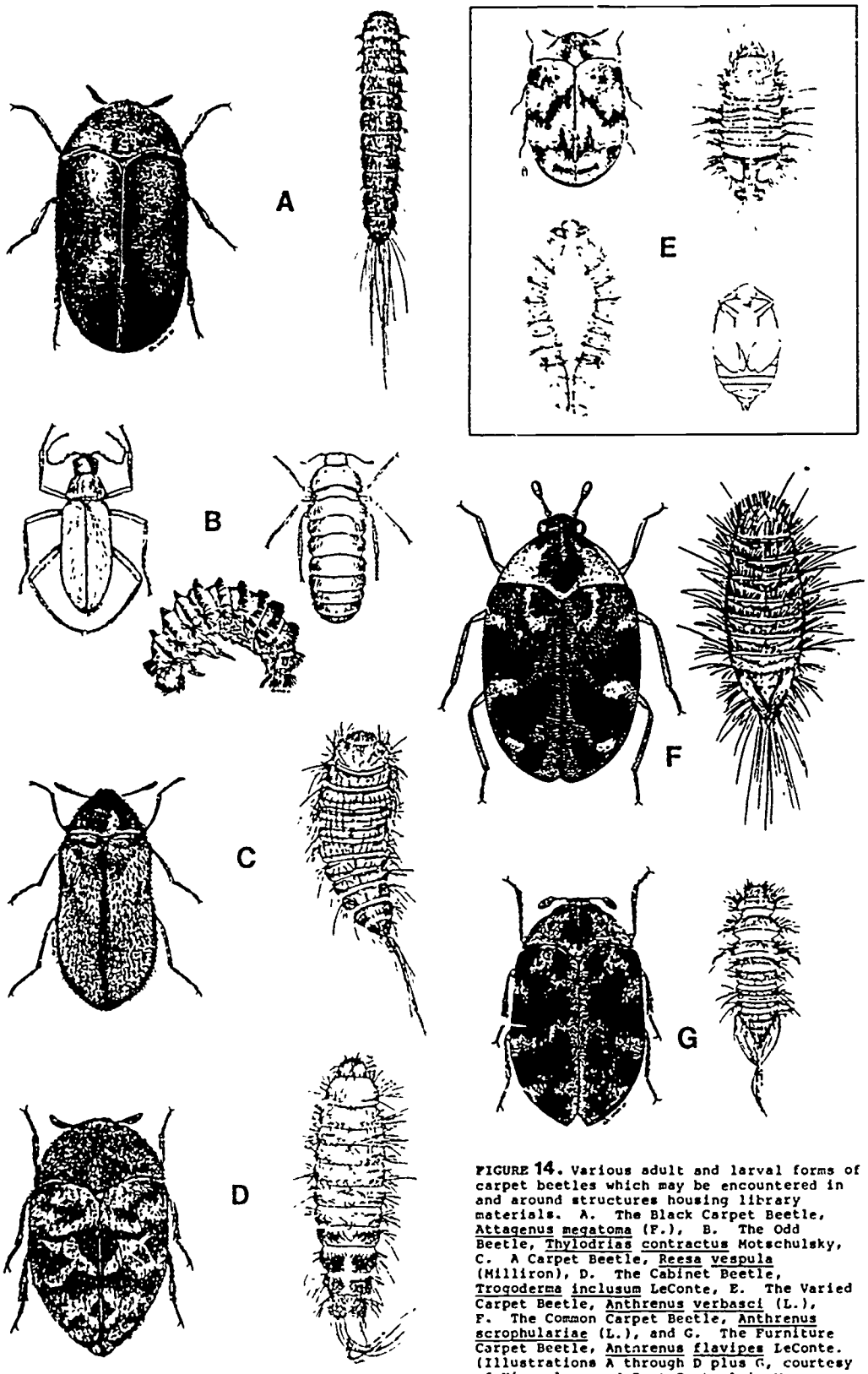


FIGURE 14. Various adult and larval forms of carpet beetles which may be encountered in and around structures housing library materials. A. The Black Carpet Beetle, Attagenus megatoma (F.), B. The Odd Beetle, Thylodrias contractus Motschulsky, C. A Carpet Beetle, Reesa vespula (Milliron), D. The Cabinet Beetle, Trogoderma inclusum LeConte, E. The Varied Carpet Beetle, Anthrenus verbasci (L.), F. The Common Carpet Beetle, Anthrenus scrophulariae (L.), and G. The Furniture Carpet Beetle, Anthrenus flavipes LeConte. (Illustrations A through D plus G, courtesy of Kingsolver and Pest Control in Museums. Illustrations E and F, courtesy of Mallis.)

embroidery; needlepoint; feathers, including those in birds' nests; rugs; objects made of horn; whale baleen; quills; wasp, yellow jacket, and hornet nests; dead insects; rodent carcasses; hair and fur; soft leather and buckskin; silk; leather book bindings; stuffed animals and birds; snake skins; horsehair stuffed furniture; brushes; woolen shoeshine buffs; feather dusters; and wool felt insulation. One carpet beetle, the odd beetle, has been found destroying valuable prints in the National Gallery, Ottawa, Canada (MacNay 1950).

The larvae are small with obvious segmentation and many hairs and bristles. The larva of the black carpet beetle is elongate and carrot-shaped and generally orange in color. The rest of the carpet beetles are shorter and generally dark in color. Most carpet beetle larvae prefer to feed in dark areas, such as at the base of the nap of a thick rug or beneath furniture. They leave behind many larval skins as they molt from one stage to the next over a period of 4 to 5 months. The larvae pupate in their last larval skin and emerge as adults to live for approximately 1 month. After egg laying, the female generally dies within a few days.

CLOTHES MOTHS

The larvae of clothes moths may be destructive in a library where they feed on items high in protein. They are particularly fond of animal carcasses, furs, feathers, hair,

wool, dead insects, taxidermy mounts, feather-filled upholstery and cushions, tapestries, carpets, felt, and sometimes bookbindings.

Four species of clothes moths are important in museums, libraries and collections. They are the webbing clothes moth, the casemaking clothes moth, the tapestry or carpet moth, and the brown house moth (Figure 15).

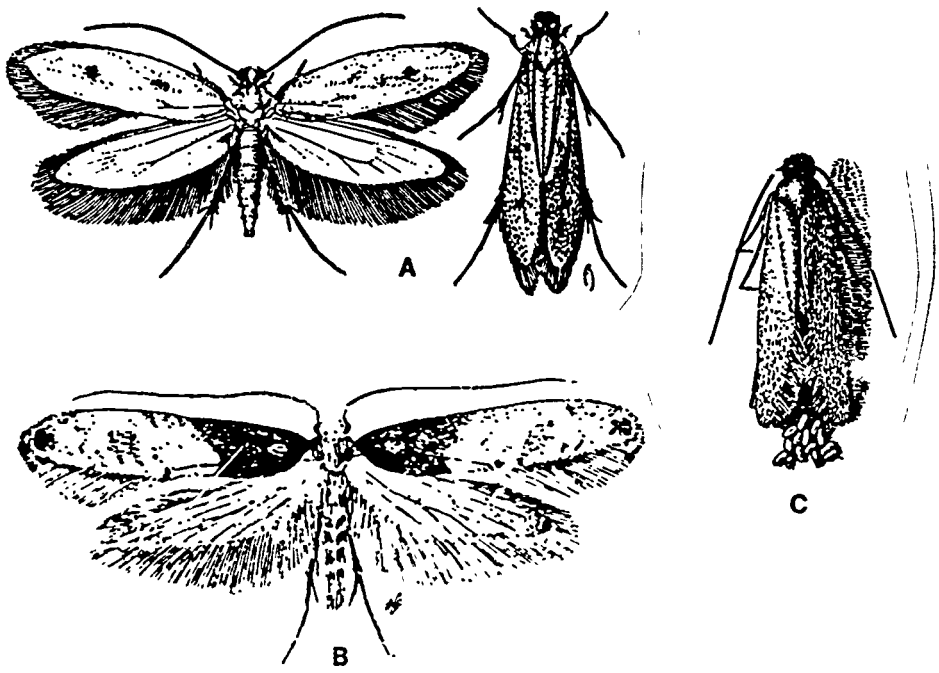


FIGURE 15. - Various fabric pest moths which have been known to infest library materials. The larvae of these moths feed on materials high in protein.
A. Casemaking clothes moth, Tinea pellionella (L.).
B. Tapestry or carpet moth, Trichophaga tapetzella (L.).
C. Webbing clothes moth, Tineola bisselliella (Hum.).
(Courtesy of Mallis)

The Webbing Clothes Moth. - The most common of the four species of clothes moths is the webbing clothes moth, which is worldwide in distribution. Its name is derived from the habit of the larvae of spinning silkened tubes and runways as they feed on an item. In addition, the pelletized frass is generally stuck together in clumps by silken webbing produced by the larvae. The larva, which is a whitish caterpillar with a brown head capsule, commonly feeds in dark, protected areas.

Adult moths of the webbing clothes moth are good fliers, but tend to fly in darkened rooms and areas. The males are primarily on the wing, whereas females generally walk. The adults have been known to fly up to 300 feet, entering structures, particularly attics. Female moths lay between 40 and 50 eggs. Egg deposition occurs in darkened areas or at night. After the eggs are laid the female dies. Upon hatching, the larvae commence feeding as soon as a suitable food is available. The newly born larvae can enter any opening greater than 0.01 millimeter, which enables them to enter all manner of storage containers. Upon reaching maturity, the larva spins a pupal case of silk and transforms into an adult moth. The time from egg to egg varies from 5 to 9 months or may exceed 2 years if the larva is triggered to go into a dormant period.

The Casemaking Clothes Moth. - This moth is not nearly so common as the webbing clothes moth, but has been found in bird and rodent carcasses, Persian rugs, and wall hangings and tapestries from Central and South America. The moth has a brownish hue with indistinct dark spots on the wings. The name casemaking clothes moth is derived from the habit of the larva to spin a case of silk which is interwoven with fibers of the article on which it is feeding. When the larva moves, this case is carried around with it, and the larva will die if separated from its case. The larva does not produce silken tunnels when feeding as does the webbing clothes moth.

The life history is somewhat similar to that of the webbing clothes moth. When the larva is mature and ready to pupate, it often leaves the product on which it is feeding and attaches its silken cocoon to objects some distance from the infested product. By attaching its cocoon in such a manner, infestations are commonly transported from one place to another.

The Carpet or Tapestry Moth. - This moth is much rarer than the previous two species and is distinctly marked, so it is easily distinguished from the other two moths. The larva makes no case; instead it fashions a silken tube or burrows through the material. This tube, combined with the feeding, causes much damage to infested material.

The adults are found flying from April to June and mate almost immediately after emergence. The female deposits from 60 to 100 eggs. The larval stage persists through the summer months. A rough cocoon is constructed by the larva for pupation. One or two generations may be produced per year.

The Brown House Moth. - The brown house moth feeds on animal and vegetable matter in many countries around the world. The larval stage feeds principally upon upholstery, carpets, furs, skins, dried specimens of animals, in birds' nests, dried plants, dried fruits, and sometimes on books. In some instances this moth has been found damaging leather bindings.

The life history of this moth is extremely variable, primarily due to variations in temperature. The incubation period varies from 8 to 110 days; the larval stage from 71 to 145 days. The larva may enter a desiccation-resistant stage prior to pupation, which may last for months. The complete life cycle in the field usually takes from 11 to 13 months.

This moth has been noted as a serious pest of books with cloth bindings (Chrystal 1932). The injury was most severe to books on shelves nearest the floor and became less pronounced and disappeared entirely as the distance from the floor became greater. The feeding of the larvae showed as regular patches of varying depths on the binding with the same type of damage

to the insides of the covers. The shelves contained massive amounts of excrement and traces of silken threads. Cocoons were found on shelving, in tunnels on the outer bindings, and between the covers and fly leaves.

TERMITES

Many kinds of termites can be found throughout the world (Figure 16). They include drywood, dampwood, furniture or

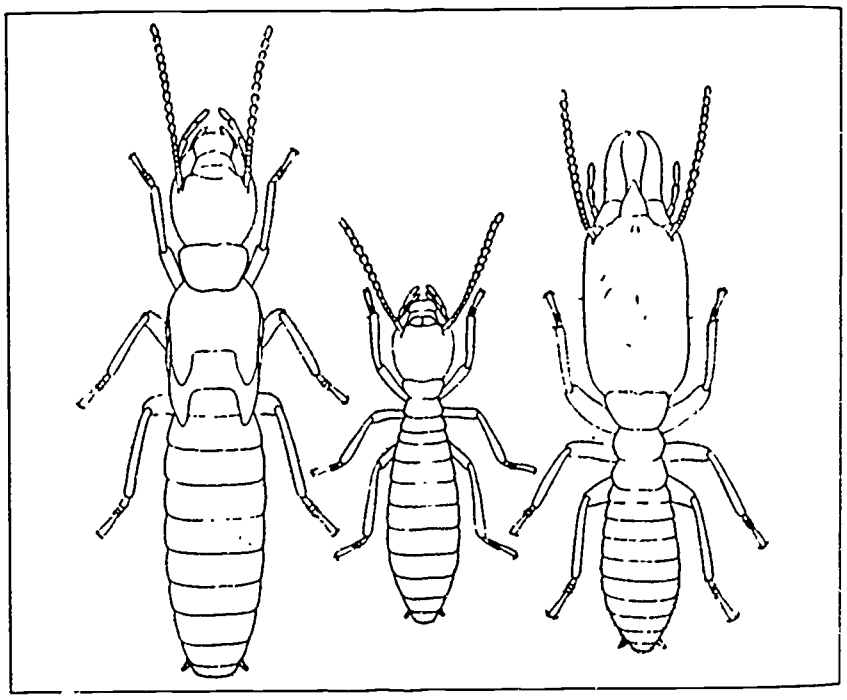


FIGURE 16. - Supplementary queen (left); worker (center); and soldier (right) of the eastern subterranean termite. (Courtesy of Mallis)

powder post, subterranean, Formosan, and desert termites, to name but a few. Termites live in colonies, are social insects, and divide their work among specialized members. The members of these colonies move in passageways that are hidden from the sun's rays and are protected from undue moisture loss (Mallis 1982). Some need moist wood to survive, some nest in the ground and move back and forth between the wood source and the colony, and others can live totally within structural members or books without attachment to the ground or a water source.

Worker termites bite off small fragments of wood a piece at a time and digest the wood fragments by utilizing a diverse array of amoebae, bacteria, spirochaetes, and fungi. The worker termites then regurgitate this digested material and feed the remainder of the colony.

Cellulosic materials make up the majority of a termite's diet. Since library materials are primarily composed of cellulose, the collections constitute a banquet for termites. Not only will the termite colony attack the structural members of the building itself, but they will consume all manner of paper products. They can be particularly destructive in storage areas where inspection of the collections is minimal.

Subterranean Termites. - Worldwide, subterranean termites are responsible for millions of dollars of damage to structures and materials annually. These ground-dwelling termites nest in soil or in wood or vegetable matter in contact with the ground. They are able to reach wood or cellulosic material above ground level by means of earthen shelter tubes which the workers construct and through which they travel. They almost always have a ground connection to the colony. Rare exceptions are known where they have been able to maintain themselves in damp wood in wet areas without ground contact. The workers cement together earth and triturated wood with saliva and liquid feces to form a mudlike cement. This tubing activity is characteristic of subterranean termites and is an aid in the identification of their damage.

The workers are the only caste in the social system that can eat cellulosic materials and digest them. They in turn regurgitate digested material to feed nymphal workers, soldiers, kings and queens, secondary reproductives, and the winged forms (alates). If a section of the colony is somehow cut off from the main colony, secondary reproductives will take over the function of egg laying in this separated colony. Control measures are aimed at placing chemical barriers in the soil between the colony and the food source.

Drywood Termites. - Unlike subterranean termites, which need a source of moisture and contact with the ground, drywood termites can colonize individual portions of structural elements, furniture, or stacks of cellulosic materials. These termites are restricted to the warmer parts of the world where multiple colonies can exist in a single building. Whereas subterranean termites tend to feed in the spring wood and with the grain, drywood termites hollow out wood from surface to surface.

A distinctive sign of drywood termites is the pelletized frass generated by the workers (Figure 17). These pellets are

FIGURE 17. - Characteristic pelletized frass (excrement) of dry wood termites. The frass will be the color of the material on which the termites are feeding.

often dumped out of the workings into a neat, conical pile through a small hole or holes which exit the galleries. A variety of control measures can be used for control of drywood termites, including chemical fumigation of structures.

MICE

The most common rodent found in libraries is the house mouse (Figure 18). This species seems to be able to invade

FIGURE 18. - The house mouse, Mus musculus Linnaeus. (Courtesy of Mallis)

practically any structure man has made. Damage to library materials comes from mice destroying materials for nesting purposes and urinating and defecating on library materials. Populations of mice can build up very quickly. When they die, their carcasses act as a source of food for carpet beetles and perhaps clothes moths. In addition to damaging collections

directly, mice may chew the insulation off electrical wires, causing them to short and start a fire. Various diseases and ectoparasites are associated with mice and their nests.

House mice are secretive and are generally active at night. They live in a territory with a small home range. The average distance that a mouse travels in its activities is a rough circle of 30 feet. Male mice are highly territorial, and for this reason control measures must be designed for specific areas where mouse droppings are found. They live outdoors year-round but will invade buildings, particularly in the fall of the year in temperate climates.

Mice are sexually mature in 35 days. The average litter size is about six. A female can have a litter approximately every 50 days. Community nests of mice are not uncommon, wherein several females may share the nest with their accumulated brood. They breed throughout the year indoors. Mice living outdoors are seasonal breeders, peaking in the spring and the fall.

Mice feed on a variety of foods provided by man. They also feed on dead insects found indoors. Mice have been found to be cannibalistic. They apparently do not need free water to drink, but will consume it if it is available. Mice

feeding on high protein diets must supplement their diets with free liquid. During their nocturnal activity mice leave fecal droppings wherever they have been active. Other signs of mouse infestations are gnaw marks; small, stained holes in floors and walls; and a pungent odor from their urine.

RATS

A variety of rats worldwide may invade structures seeking out food and shelter. The most common rat encountered in urban situations is the Norway rat (Figure 19). Rats are

FIGURE 19. - The Norway rat, Rattus norvegicus (Erxleben). (Courtesy of Ware)

important with respect to library collections because of their habit of gnawing on papers, books, and like materials for nesting material. They also can create damage to the structure itself by gnawing holes in structural timbers, doors, windows, and other building elements to gain access to food, water, and nesting sites.

The diseases of rats are well documented. Such diseases are plague, murine typhus fever, infectious jaundice, rat-bite fever, trichinosis, and others.

The female Norway rat often digs a burrow system in soft earth in which to raise her young. In most cases the burrow is located on the exterior of a building in a protected location. Occasionally this activity will enable rats to burrow into crawl spaces of buildings. In some instances rats will be found in the sewer system and may enter buildings through piping. Since rats are good climbers, they will occasionally enter buildings above ground level.

The Norway rat is a moisture-loving creature and of necessity must live near an available supply of water. It is omnivorous, but shows a preference for grain, potatoes, fruit, and eggs. Rat droppings will take on the color of the diet consumed over the previous 3 days.

Rats are capable of breeding every month of the year. The average number in a litter of Norway rats is usually six to eight. The female has an average of three to six litters per year. The young are born helpless, pink, blind, and naked. In 12 to 14 days they open their eyes and are ready to leave the nest in about a month.

MOLDS AND MILDEW

A recurrent problem in libraries, particularly in subtropical and tropical climates, is the presence of mold on library materials (Figure 20). Mold results when spores land

FIGURE 20. - Heavy mold damage to books in a library storage room. A failure in the automatic humidifying system produced conditions which brought on this serious situation.

on a substrate that has the correct temperature and surrounding humidity to initiate their germination. When spores germinate, they put out fine strands of mycelia, which invade the substrate and use it as a food source. The mold mycelia exude liquid enzymes that dissolve the substrate, and this food is then used in the production of more mycelia and eventually millions of spores.

Each cubic foot of air contains thousands of mold spores which land on surfaces and objects in the library every day. Attempts at mold control in library materials by using various chemicals therefore is usually ineffective. Chemicals such as thymol, ortho phenylphenol (OPP), alcohol, and dilute bleach solutions kill some of the mold spores on the surface as well as some of the mycelia. As soon as these chemicals have volatilized from the surface, the object is again vulnerable to new mold spores that land on its surface. If conditions are correct, the spores will germinate and more mold will be produced. These types of chemicals do not impart residual control for mold or mold spores.

Similarly, fumigation with poisonous gases in a chamber does not impart any residual mold-control effects. Much of the fumigation that is done in libraries is not warranted. Changing the environment that produces the conditions suitable for mold growth in the first place is the only effective means of retarding and eliminating mold growth. If a spore lands on

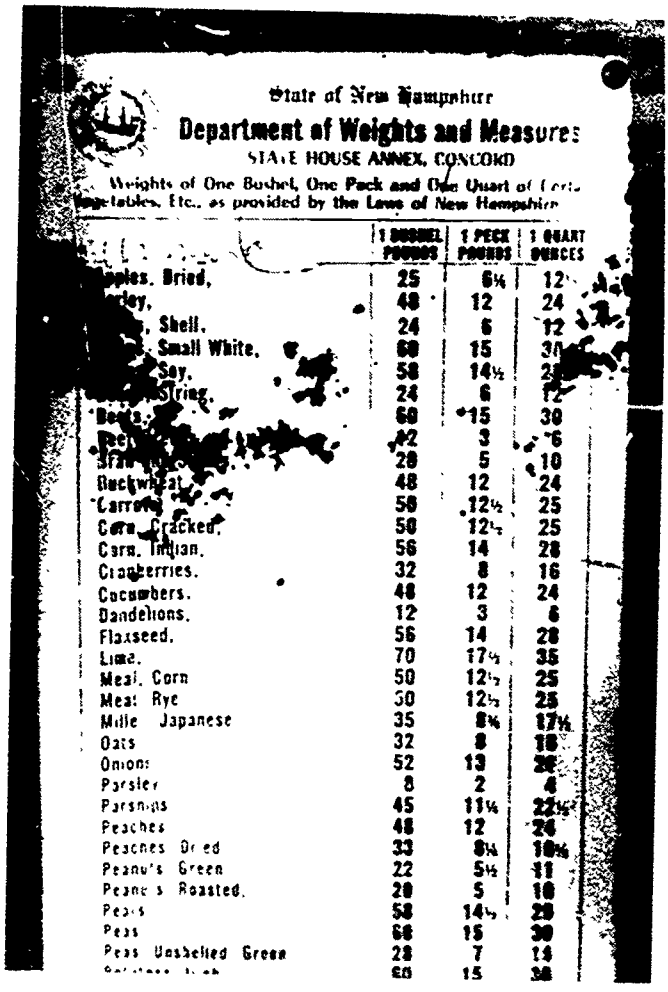
a substrate which is not suitable for growth, and the humidity and temperature conditions surrounding the spore are inadequate to trigger spore germination, in time the spore will desiccate and die. As long as the conditions of the substrate and surrounding microenvironment are not suitable for spore germination, the spores will not germinate and mold will never appear. If mold is present on materials, moving them to a drier, less humid area will stop the mold growth and the spores will eventually desiccate and die.

RECOGNITION OF DAMAGE CAUSED BY PESTS IN LIBRARIES, ARCHIVES, AND THEIR COLLECTIONS

The starting point for any Integrated Pest Management Program is a thorough inspection of the facility and collections to determine the status of past, current, or potential pest problems. The most difficult part of such an inspection, once damage or signs of infestation have been found, is to determine if the situation is current and active or if it is a previous infestation and therefore inactive. Holes and galleries in books will not disappear once an infestation ceases. nly a trained eye can determine if activity exists and control or prevention measures are warranted.

SILVERFISH

Damage to paper products from silverfish is caused by their direct feeding on the materials. The feeding of silverfish results in irregular feeding areas that exhibit characteristic "thin spots" (Figure 21). Silverfish do not



State of New Hampshire

Department of Weights and Measures

STATE HOUSE ANNEX, CONCORD

Weights of One Bushel, One Peck and One Quart of Certain Vegetables, Etc., as provided by the Laws of New Hampshire

	1 BUSHEL POUNDS	1 PECK POUNDS	1 QUART OUNCES
Apples, Dried,	25	6¼	12
Barley,	48	12	24
Beans, Shell,	24	6	12
Beans, Small White,	60	15	30
Beans, Lay,	58	14½	29
Beans, String,	24	6	12
Beets,	60	15	30
Buckwheat,	12	3	6
Bran,	20	5	10
Buckwheat,	48	12	24
Carrots,	50	12½	25
Corn, Cracked,	50	12½	25
Corn, Indian,	56	14	28
Cranberries,	32	8	16
Cucumbers,	48	12	24
Dandelions,	12	3	6
Flaxseed,	56	14	28
Lime,	70	17½	35
Meal, Corn	50	12½	25
Meal, Rye	50	12½	25
Millet, Japanese	35	8¾	17½
Oats	32	8	16
Onions	52	13	26
Parsley	8	2	4
Parsnips	45	11¼	22½
Peaches	48	12	24
Peaches, Dried	33	8¼	16½
Peanuts, Green	22	5½	11
Peanuts, Roasted,	20	5	10
Pears	58	14½	29
Peas	60	15	30
Peas, Unshelled, Green	28	7	14
[illegible]	60	15	30

FIGURE 21. - Silverfish feeding on paper. Note the lace-like appearance of the feeding. Silverfish do not have strong mouthparts and tend to abrade the surface until they break through.

have strong chewing mouth parts and therefore tend to sit on the surface of the paper and gradually abrade the surface. In some areas of the damage, the feeding will result in irregular holes in the paper. In other areas, however, the feeding will not break entirely through the paper and will result in thin spots or simply the removal of the printed word (Figure 22).

FIGURE 22. - Silverfish feeding on a framed print. Note the white areas on the child's face where silverfish have abraded the surface.

When silverfish feed on printed materials, they often leave a fine, pelletized frass (excrement) which is black and resembles a miniature mouse dropping. Under magnification, this residue is fairly easily distinguished as individual pellets or droppings. This material accumulates under items or may be scattered randomly over surfaces in darkened areas. It may also be found on the interior of acid-free storage boxes. Large amounts of frass may be found in attics insulated with cellulose insulation (ground up newsprint).

THE "BOOKWORMS"

Feeding damage from bookworms is primarily caused by the grub-like larvae. Eggs are usually laid at the edges of the cover or on the spine, and the newly hatched larvae begin to chew their way and tunnel up the spine, in between the cover and flyleaf, or immediately beneath the cover. These frass-packed galleries meander undetected until the book is opened. The galleries will begin with a small diameter and increase in size as the larva molts to larger and larger sizes.

A flashlight inspection of the shelving can easily find indications of bookworm feeding activity. As the larvae continue to feed and as the adults chew their way out upon emergence, powdered frass falls in a pile on the shelving. This frass will be the color of the cover of the book. It can

be found as piles immediately adjacent to the base of the book on the shelf or as piles on the top of the book at the edge of the cover as it stands on the shelf. These piles of frass connote an active infestation (Figure 23).

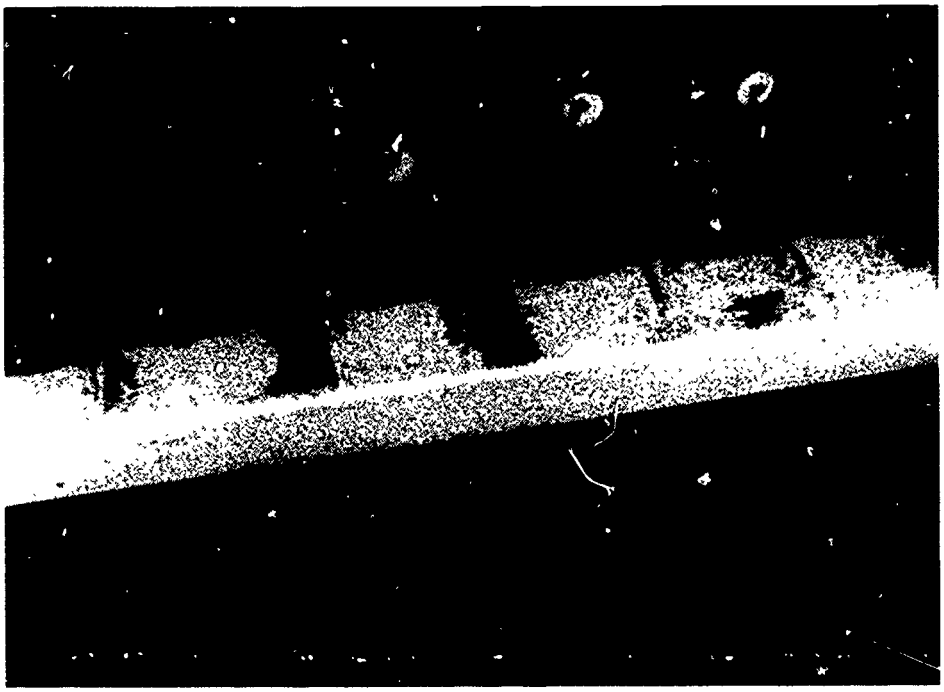


FIGURE 23. - "Bookworm" frass (excrement) left as piles of powder on the shelving is a sign of active feeding. The piles of frass will be the same color as the material on which they are feeding, in this case, black book bindings.

Small, round holes in the spine, cover, or pages of a book, left as larval galleries or adult exit holes, will remain for the life of the book, even though the "infestation" may not be active (Figures 24, 25 and 26). If no frass piles are found on or adjacent to the book, the infestation is not

FIGURE 24. - "Bookworm" exit holes left behind by emerging adult beetles. The emergence of adult beetles will also result in piles of colored frass.

FIGURE 25. - Larval galleries made by "bookworm" larvae, in this case, the cigarette beetle.

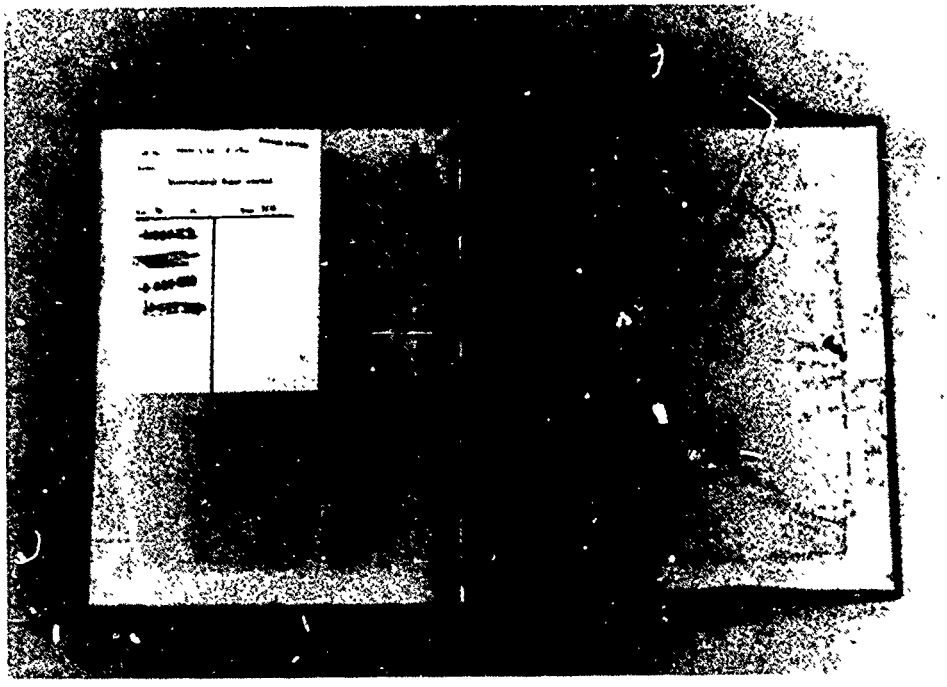


FIGURE 26. - Larval galleries made by cigarette beetle larvae are so extensive that the cover has fallen off this book.

active and therefore no remedial action need be taken. Often unnecessary fumigation is performed on books exhibiting old evidence of bookworms that have long since died out. Bookworms require an environment with high moisture content, and often infestations die out naturally when infested books are moved to drier locations.

COCKROACHES

The feeding damage of cockroaches to books is primarily done by the large species, such as the American, Australian, and the oriental roach. The American roach is probably responsible for most of the feeding damage on book covers and paper products. Large roaches have strong, chewing mandibles and bite off bits of cover and paper.

The feeding damage of large roaches is ragged in appearance and often begins at the edges of magazines and paper products (Figure 27). With repeated bites, large, excavated, ragged holes and depressions will result. The feeding on book covers resembles mold at a distance, but when viewed close-up, it is easy to see a puckered effect on the

FIGURE 27. - American cockroach feeding damage to paper products. Note the cockroach egg case in the center of the photograph.

cover as individual bites have been taken out of the cover by the roaches. Large, irregular patches of feeding damage occur on covers and spines. Cockroach feeding will often remove the surface layer and begin to break into the fibers of the cloth cover (Figure 28). With leather covers, the feeding may commence all the way to the backing.

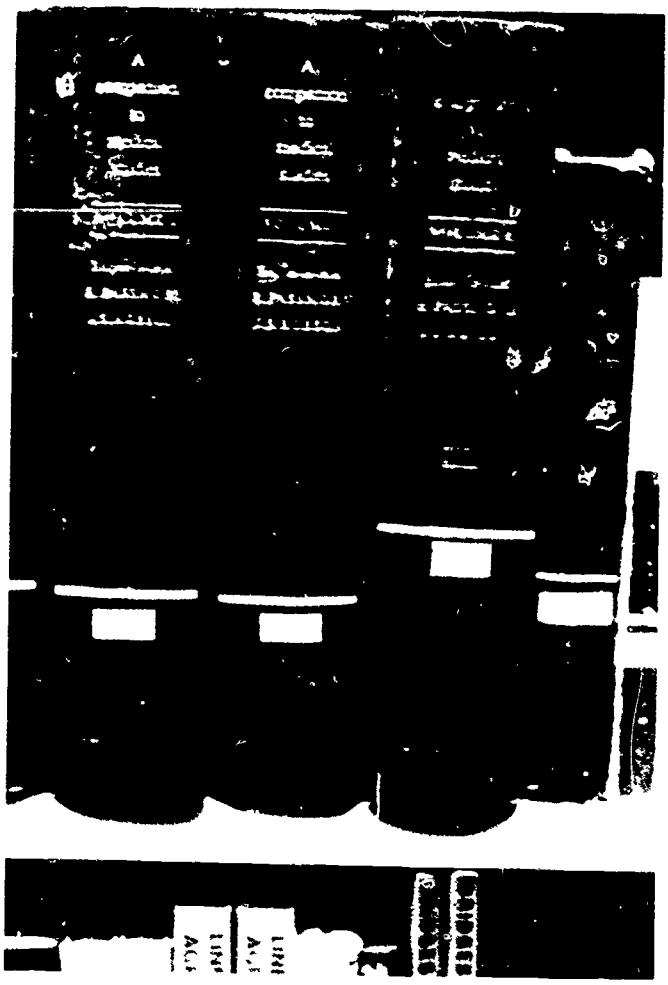


FIGURE 28. - Cockroach feeding damage to book covers. This amount of damage can result from a single night's feeding of American cockroaches.

American roaches leave other signs and evidence while feeding on books and paper products. They regurgitate a brown liquid called attar while feeding and resting on materials.

This attar, which contains chemical pheromones that act as an attractant to other cockroaches, is called an aggregation pheromone. Often smears and tear-shaped droplets of this brown liquid will be left behind (on books and library materials.

American roaches may leave behind pelletized excrement on or around the products on which they are feeding (Figure 29).

FIGURE 29. - Pelletized frass (excrement) left behind on books by American cockroaches.

The pellets are very distinctive in shape and will be the color of the material on which the roaches are feeding. Most of the time the pellets are dark in color (Figure 30). They

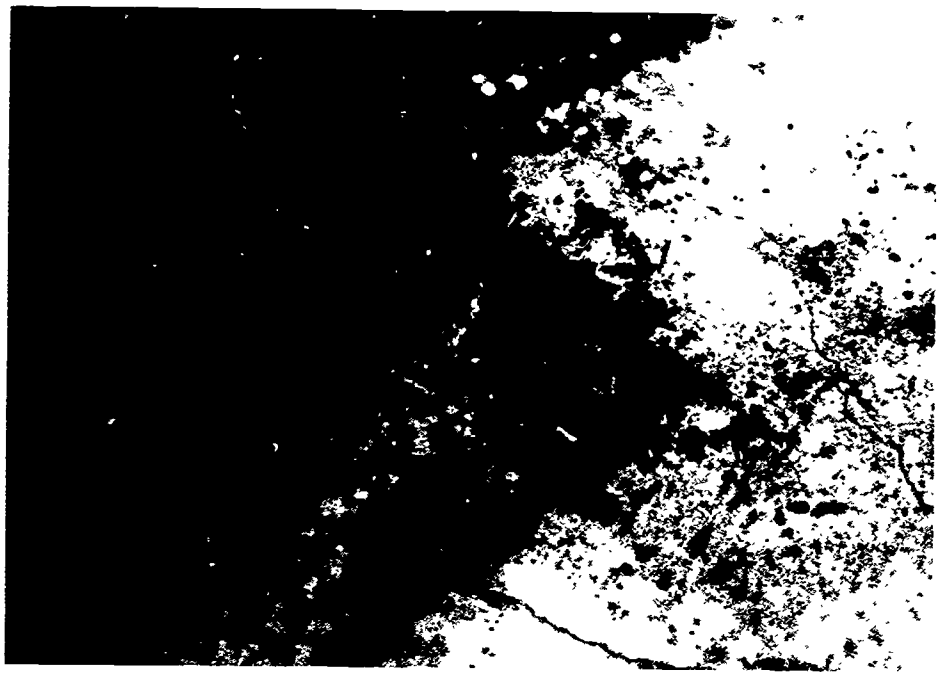


FIGURE 30. - A pile of pelletized frass from American cockroaches on the floor at the base of a wall. A large number of cockroaches have been using this wall as a daytime retreat.

are approximately 1/8" in length with blunt ends and longitudinal striations. These striations or ridges easily separate this dropping from a typical mouse dropping (Figure 31). Even though they are similar in size, the mouse dropping is generally smooth and has a tapered point.

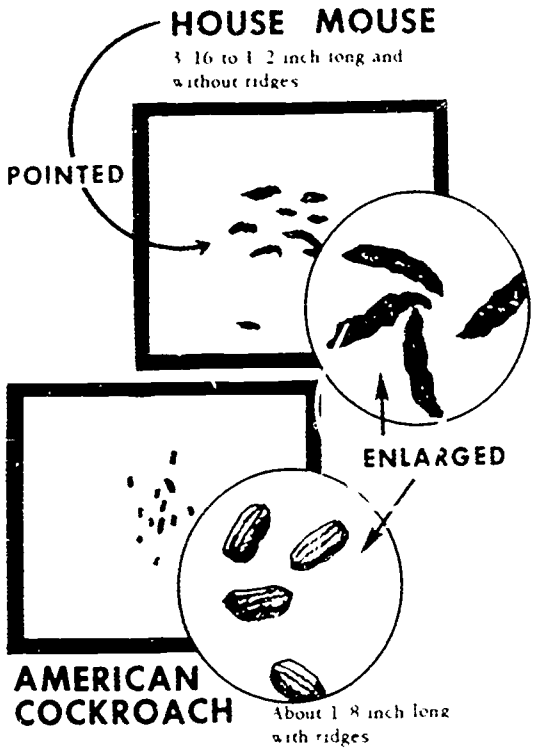


FIGURE 31. - A comparison of house mouse and American cockroach droppings. American cockroach droppings are uniform, blunt-ended with longitudinal ridges, whereas house mouse droppings are irregular and tapered with no ridges.

Often American roach droppings are mistaken for mouse droppings and inappropriate pest control measures are taken. By misidentifying the droppings, baiting for mice will only aggravate the roach situation. Large cockroaches will readily feed on rodent baits without being affected by the toxins of the bait.

PSOCIDS OR BOOKLICE

As previously discussed, booklice do not directly feed on paper products. They feed on microscopic molds which grow on paper products when they are stored in damp situations. By removing the paper products from these moist environments, the mold conditions will cease and the booklice will be eliminated.

CARPET BEETLES

Feeding of carpet beetle larvae results in characteristic frass drifting from the infested piece. The frass is a uniform powder made up of tiny granules. This powdered excrement or frass will be the color of the product on which the larvae are feeding. If they are feeding on dead insects, the powdered frass will generally be gray or tan. Feeding on a colored material will result in frass of the same color.

Another indication of carpet beetle feeding is the existence of cast larval skins. These hollow shells are left behind as the larvae molt from one stage to the next. Live, active carpet beetle larvae move quickly when exposed to light or may "play possum" when disturbed. The feeding is a series of neat, small, irregular holes in the item.

CLOTHES MOTHS

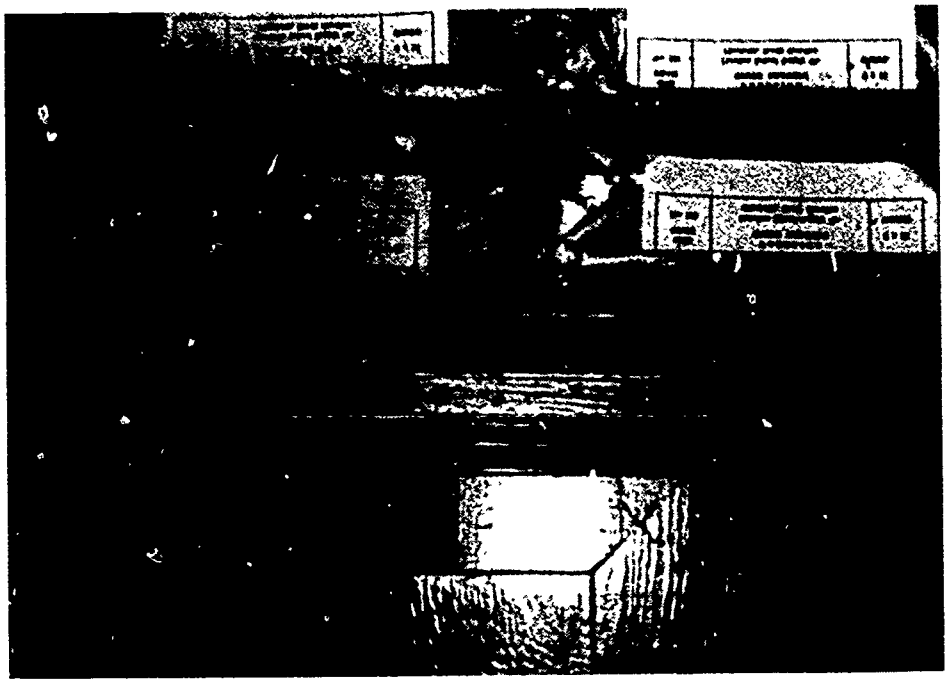
Infestations of moths are characterized by webbing, cocoons, or cases, with copious amounts of pelletized frass stuck together with the webbing. The infested material appears to be festooned with clumps of frass, webbing, and cocoons (Figure 32). Often the webbing and cocoons will

FIGURE 32. - Silken, tubular trails spun by the larvae of webbing clothes moths as they forage on a woolen rug.

extend some distance away from the infested product. On occasion larvae can be seen leaving the infested piece and moving to quiet, dark areas to spin a cocoon and emerge as an adult moth. Dead moths may also be found in the webbing associated with the infestation.

TERMITES

Subterranean termites construct earthen shelter tubes from the soil up into bookcases, books, or boxes of materials stored in basements. The key to identification of subterranean termite infestations is the presence of worker termites in the galleries and the presence of copious amounts of dirt (Figure 33). These grains of earth are cemented into hollow shelter tubes which act as humidity controlled highways for the termites while they feed on cellulosic materials. Once a book containing an infestation of subterranean termites has been removed from the shelf and the highway to the colony has been broken, the workers and soldiers that are trapped in the book will eventually desiccate and die. Once this attachment to the subterranean colony has been broken, thus cutting off the workers from the remainder of the colony and their moisture source, no further need for control is required for the infested item. The structure itself, however, should be treated for subterranean termites by a professional pest control company.



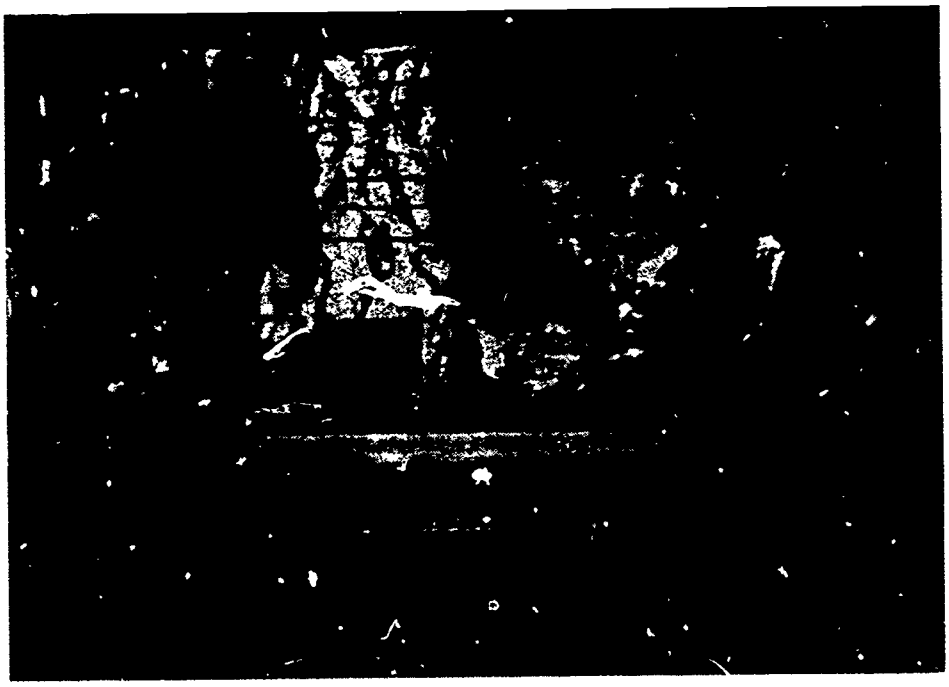


FIGURE 33. - Reams of paper damaged by subterranean termites. The photo on the top shows the reams in an undisturbed setting. The bottom photo shows the wrapping removed to expose extensive damage.

Drywood termites need no attachment to a colony in the ground and therefore can infest stacks of books or paper products as a distinct colony. Drywood termite damage is distinct for two reasons:

1. The workers excrete a pelletized frass the color of the material on which they are feeding. These piles of pellets appear under magnification to resemble a partially deflated football (Figure 17). All pellets in the pile look alike with respect to color, shape, and size.

2. No dirt will be associated with the galleries and workings, and the workers will hollow out the infested item from cover to cover. The galleries are smooth and clean. Workers will eat winter and spring wood and will not necessarily eat with the grain of the wood.

MICE

Mouse damage to library materials usually results from their habit of chewing materials for nesting purposes and

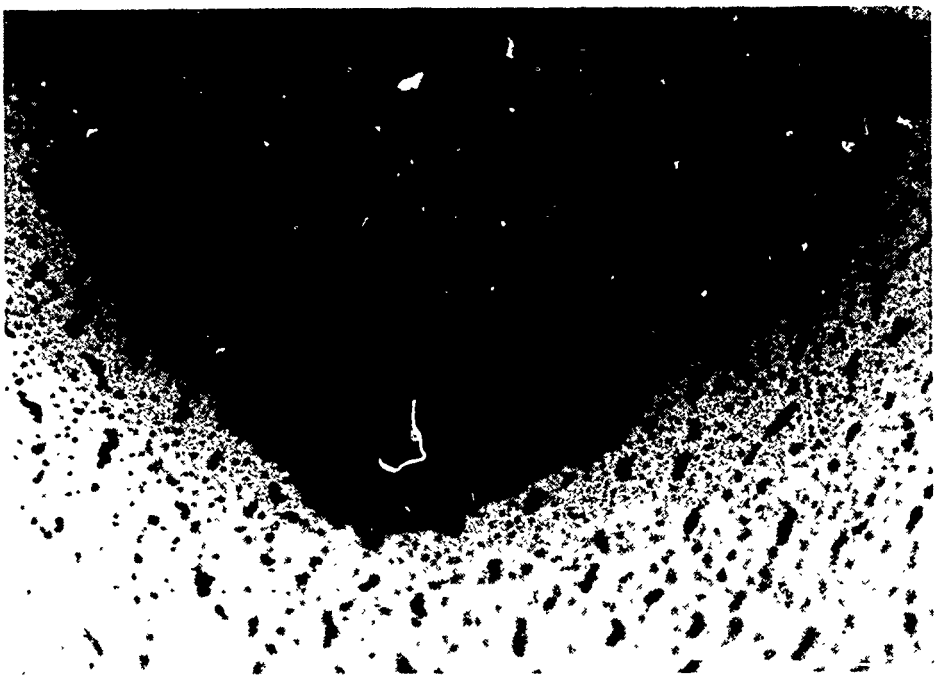


FIGURE 34. - An acoustical ceiling tile showing urine stains from house mice.

urinating and defecating on the materials (Figure 34). Mouse droppings (Figure 31) are smooth, dark, and usually pointed. Stains result from mice urinating on materials. Chewing damage can be recognized by the existence of a mouse nest within the immediate vicinity of the damage (Figure 35). Sometimes teeth marks will be left in the materials. Rodents have two incisor teeth on the upper and lower jaws. Distinct, double bite marks are an indication of mouse damage.

FIGURE 35. - House mouse damage to a drawer of historic wall paper rolls. The rolls have been chewed up for nesting material.

RATS

The kind of damage inflicted by mice can also be done by rats, but is encountered much less frequently. Rats generally nest outdoors in earthen burrows and do not normally damage materials directly. However, they will urinate and defecate

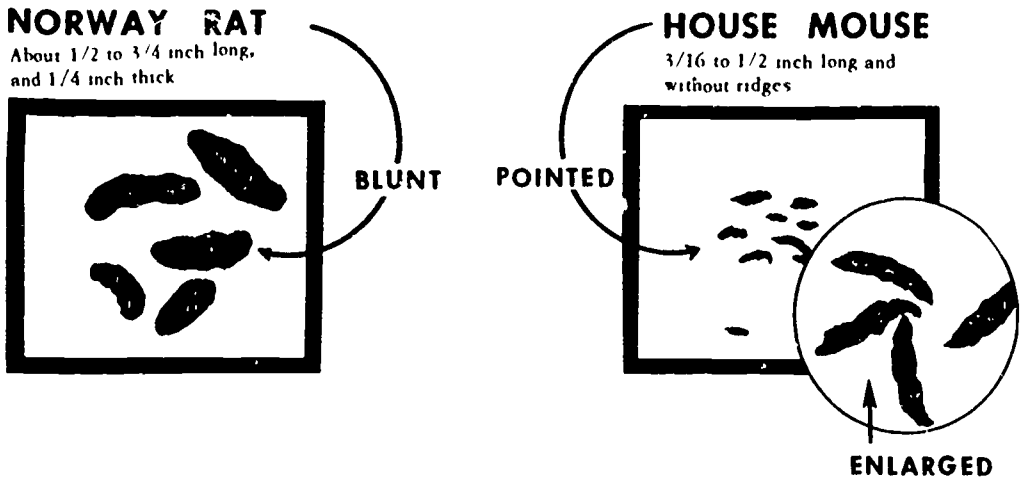


FIGURE 36. - A comparison of the droppings of the house mouse and the Norway rat. Rat droppings are large, with blunt or rounded ends.

on materials. Rat droppings (Figure 36) are large and oval in outline and will be found in quiet, protected corners of a room. Occasionally teeth marks may be found in the damaged materials where the upper and lower incisors have left their imprints, which will be much larger than those of a mouse.

THE ROLE OF INSECTICIDES IN LIBRARY INSECT CONTROL PROGRAMS

A review of the literature pertaining to pests of library and archival materials reveals that librarians responsible for protecting collections have used a myriad of chemical approaches to control and prevent pests. Many of these materials were used in combination with binding pastes and glues as well as on the bindings themselves. Often potions and formulations were wiped or sprayed on the shelving and books.

Some of the chemicals used in the past seem almost silly today. Some are acutely toxic. A partial listing of chemicals used as dips, sprays, in combination with glues, or as wipes on books follows:

Alum
Arsenic
Benzine soak
Borax
Camphor
Colocynth
Copper sulfate
Corrosive sublimate
Creosote
Formalin
Kerosene
Lime
Mercuric chloride
Oil of anise
Oil of birch
Oil of red cedar
Pepper
Porpoise oil
Pyrethrum powder
Rotenone
Sodium fluoride
Sodium fluosilicate
Strychnine
Thymol
Turpentine
Vaseline

Care should be taken in handling some of the older volumes, particularly if they seem to have discoloration or staining which may indicate previous treatment. Fortunately some of the older remedies will have dissipated, such as various oils, camphor, kerosene, formalin, creosote, pyrethrum powder, thymol and turpentine. However, some of the more toxic chemicals, such as arsenic, mercuric chloride, sodium fluoride, sodium fluosilicate, and strychnine may remain as deposits on the materials.

When working with older volumes, management should be aware of the possibility of toxic substances on the materials and instruct personnel to wear rubber or cloth gloves. Individuals should be instructed not to touch themselves and to wash their hands thoroughly after handling the materials and prior to smoking or eating.

As previously discussed in this paper, certain insecticide formulations, when sprayed on surfaces, can release molecules of insecticide and solvents into the air. If any spray program is to be instituted in a library, spray formulations must be chosen that contain no solvents, volatilize minimally, exhibit long residual properties, and are odorless.

Spraying programs, based on the likelihood of infestation in a library, are primarily aimed at the control of silverfish and firebrats, cockroaches, carpet beetles, booklice, and

spiders. By using wettable powder or encapsulated formulations as the basis for a spray program, quarterly spray applications should suffice. In more tropical areas the frequency may have to be increased to monthly spraying, particularly on the exterior. Such products as encapsulated diazinon (Knox-Out 2FM), encapsulated chlorpyrifos (Dursban ME), propoxur wettable powder (Baygon), bendiocarb wettable powder (Ficam W or Ficam Plus), or cypermethrin wettable powder (Demon WP) are examples of materials which may be used in a residual spraying program.

For German cockroach control, insect growth regulators may be used along with the residual insecticide to enhance control. An insect growth regulator in the environment of a German roach infestation will result in last instar nymphs molting into twisted wing adults which are sterile. Methoprene (Dianex) and hydroprene (Gencor) are in common use today.

Chemical baiting programs are particularly helpful in controlling cockroaches. Two products that are readily accepted by the large species of cockroaches, and have been shown to give excellent control are propoxur bait (Baygon 2% Cockroach Bait) and boric acid paste (Blue Diamond MRF 2,000 Paste). Applications of very small amounts of Baygon 2% Cockroach Bait should be applied to quiet corners, along walls, elevator shafts, boiler rooms, false ceilings and other

areas where large roaches hide during the daytime. In their nightly forays the cockroaches will find these bait particles, consume them and be killed immediately. Pastes should be used sparingly where roaches hide during the daytime.

A bait trap has been successful in eliminating populations of the German cockroach. Hydromethylon roach bait traps (Maxforce or Combat) are currently in use in commercial kitchen and vending areas for the control of German roaches. Immatures and adults seek out the bait trap for harborage. Once inside, they consume a small portion of the bait, crawl away from the trap, and die. These child-proof traps are extremely effective in German roach control, particularly if they are used on vertical surfaces in areas of infestation. The previously-mentioned Blue Diamond boric acid paste may also be used for German roach control.

EXTERIOR AND INTERIOR RODENT CONTROL PROGRAMS

For rat control, exterior baiting programs should suffice to eliminate populations. Child-proof bait stations, such as those available from Bell Laboratories or J. T. Eaton and Company, should be paced in outdoor areas where rats are likely to burrow or follow walls to gain access to the building. Various rodent baits are available for baiting these large rat cafeterias. Bromadiolone (Contrac and Maki), warfarin (Final), chlorophacinone (Rozol), or diphacinone (Eaton's Bait Bitz) are examples of rodenticides that may be used in an exterior baiting program.

Rodent baits should not be used in interior situations under any circumstances for a number of reasons:

1. Often carpet beetles are brought into a library in rodent bait. Their eggs will hatch, the larvae will consume the bait, and adults will fly to other parts of the library to infest materials.

2. Rodent baits often act as food sources for cockroaches, particularly the large species.

3. If toxicants are used to kill mice on the interior, their carcasses will act as a food source to generate large populations of carpet beetles.

Traps or glueboards, or both, should be used for the control of mice on the interior of a library. The carcasses of the trapped mice can then be discarded. Traps and glueboards, which can be baited with a cotton ball smeared with peanut butter, should be placed in quiet corners, closets, storage areas, basements, attics, and in the immediate vicinty of mouse droppings.

THE USE OF FUMIGANTS FOR PEST CONTROL

The use of toxic fumigants in the library community has been popular for many years. D. B. Mackie of the California Department of Agriculture is credited with devising a

fumigation system in 1930 that utilized the principle of vacuum fumigation. It was in 1932 that Thomas M. Iiams used this approach with ethylene oxide and carbon dioxide to fumigate rare books and manuscripts in the Huntington Library. The use of ethylene oxide for the fumigation of library materials soon became the standard in the library community.

Various fumigants have been used in "chambers", even before the advent of vacuum fumigation techniques. Such gaseous fumigants as methyl bromide, ethylene oxide, hydrocyanic gas, carbon disulphide, methyl formate, ethylene dichloride/carbon tetrachloride, and sulfuryl fluoride have been used in chambers for the fumigation of books and library materials. In many cases the fumigation of all incoming goods is routine before they are brought into the library. Most of this type of fumigation is unwarranted and may create health hazards for personnel.

Only two groups of pests found in library materials may require fumigation with toxic gases: bookworms and drywood termites, because they tunnel so deeply inside the materials.

As previously stressed, fumigation will not control mold and mildew if the library materials are returned to the same conditions from which they came. In many instances library materials that have been fumigated for mold are later stored

in areas which do not have an environment conducive to mold growth. The fumigation is given as a reason for the successful control of mold and mildew when in fact the new area in which the materials have been placed is the governing factor in the mold and mildew control.

As research takes a closer look at many of the fumigants, hazards to human health, both acute and chronic, are becoming more obvious. Ethylene oxide, either in combination with freon or carbon dioxide, has been found to be a carcinogenic material. In the United States a chamber must have no more than 1 ppm of ethylene oxide left after aeration before the materials can be removed safely. One of the major problems with ethylene oxide is that very few chambers in the world meet this requirement. Any fumigation chamber relying on an airwash system to aerate the goods after fumigation has been completed, usually will not reach levels of 1 ppm or below at the end of the airwash cycles.

An airwash cycle is a term coined by the manufacturers of chambers to mean one complete cycle of "air washing" of the goods inside the chamber after exposure to a toxic gas. At the end of the exposure phase, the chamber is under vacuum. The operator, either manually or electronically, allows fresh air to come into the chamber. Another vacuum is then drawn, removing some of the toxic air by expelling it to the

atmosphere. After a vacuum has been drawn, fresh air once again is allowed to rush into the chamber. Then another vacuum is drawn, and this contaminated air is once again expelled to the atmosphere. This series of alternation between pulling a vacuum and allowing fresh air to rush into the chamber is termed an airwash cycle. Most chambers are set up to allow for up to five total air washes before the electronics must be reset.

After such a limited number of airwash cycles, a chamber rarely meets the current standard of 1 ppm residual ethylene oxide. Studies have shown that in some chambers after 75 airwash cycles 4 ppm still remained in the chamber. In designing, modifying and testing chambers, it is difficult, if not impossible, to reach such low levels without a flow-through ventilation system. Even with a flow-through ventilation system, depending on the materials being fumigated, 1 pmm is difficult to obtain with ethylene oxide.

A study performed by the Center of Occupational Hazards, which surveyed the use of ethylene oxide fumigation chambers in 11 New England institutions in 1984, found that most operators perform one to four airwashes before removing the goods from the chamber. Some relied on window fans, air-conditioning units, or separate exhaust systems to vent the gas to the atmosphere. Most did not regularly monitor ethylene oxide levels nor did they meet current OSHA (Occupational Safety and Health Act) standards.

The negative properties of fumigating library materials with ethylene oxide must also be considered. Ethylene oxide is used industrially to increase the wet strength of paper by reacting with the paper cellulose to create another, stronger molecule. Conservationists should be aware that using ethylene oxide on cellulosic materials such as paper and textiles changes the very nature of the material (Peltz and Rossol 1983). Other undesirable effects of ethylene oxide fumigation include the loss of adhesiveness of gum arabic and animal glues, increased solubility of some paints and pigments, and a cross-linking reaction with protein materials which prematurely ages them and makes them brittle. In addition, some researchers have found that materials fumigated with ethylene oxide for mold control are actually more prone to mold attack and growth after the fumigation than before.

Ethylene oxide is soluble in oils, fats, and lipids, making leather-bound books retain ethylene oxide for long periods of time after fumigation. After bringing books out of a chamber, they will volatilize ethylene oxide into the air for varying periods of time up to and exceeding 3 months. It is therefore critical that the management of major libraries test in-house chambers and study fumigation policies and procedures to determine if they are meeting current requirements. Most will find that fumigation chamber modifications and procedural changes are required to meet current standards.

Other fumigants such as methyl bromide, hydrogen sulfide, and some of the liquid fumigants are not generally acceptable for library materials for several reasons. Methyl bromide sometimes chemically reacts with materials high in sulfur. If this chemical reaction takes place, mercaptans are formed creating an irreversible, foul-smelling odor. Hydrogen sulfide is explosive and dangerous to use. Some of the liquid fumigants have been found to be carcinogenic and are very poor ovicides (egg killers).

Recently in the United States Vikane (sulfuryl fluoride), manufactured by Dow Chemical Company, has been registered for use in chambers as a fumigant. As with all fumigants, this material does not impart any residual control, but can effectively penetrate dense materials, such as library materials, and will kill all stages of insects. Vikane is, however, a poor ovicide and therefore dosages must be increased in order to penetrate the eggs of certain species of insects, including those of bookworms.

To date this material has been found to be fairly non-reactive with materials and is commonly used as a structural fumigant in wood-destroying insect control. Recent research on Vikane (The Getty Conservation Institute 1987) has shown that Vikane may tarnish and discolor metals and that it will cause changes in the physical properties of cellulose. A

team from the University of Florida, under the direction of Nan-Yao Su, is investigating the lowest amount of Vikane needed to eliminate beetle adults, larvae, and eggs in an effort to minimize the effects of Vikane on materials.

ALTERNATIVE PEST MANAGEMENT METHODS

Insect Growth Regulators - As previously discussed in this paper, certain insect growth regulators are currently being used in pest prevention and control, specifically to control fleas, ants and German cockroaches. They may be of use in ant and cockroach control in libraries. These non-toxic materials affect either the ability of insects to properly molt and mature or their reproductive capability.

Habitat Modification - The management of pests infesting collections may be realized in some instances by maintaining a constant environment. Certain pests, such as bookworms, silverfish, booklice, and mold, are more likely to develop in moist environments. By maintaining relative humidities in the 50 percent range, the rapidity with which they develop and the suitability of the food source can be altered. Even if sophisticated air-conditioning systems cannot be installed, the use of fans to circulate air will eliminate pockets of high moisture which may occur in "dead spaces" in stacks and collections, particularly at floor level.

MECHANICAL AND PHYSICAL CONTROL

As will be detailed later in this study, specific measures may be used to physically keep insects and rodents from invading a structure or collection. Screening windows; screening air intakes and louvers; weatherstripping exterior doors; installing bottom rubber door flaps and thresholds on doors; sealing areas where pipes penetrate walls with copper wool; placing caps or screening, or both, on unused chimneys; and sealing exterior roll doors with brushes attached to their frames will help to keep insects and rodents from penetrating the interior.

Proper lighting of the structure is important so that insects are not attracted to a building. The use of high-pressure sodium vapor lighting is superior to mercury vapor, fluorescent, or halide lighting. The latter three give off high amounts of ultraviolet light, which is highly attractive to nocturnal insects. Whenever possible, focus lights at a building rather than attaching them to the building. The insects will then be drawn to the point source of light away from the building.

Ornamental plantings around the building should be carefully planned so that carpet beetles are not attracted to the building. Carpet beetle adults feed on flowers high in pollen content. They are particularly fond of multiple heads

of blue or white flowers. For this reason plants such as Spirea (Bridle Veil), daisies, and asters should not be planted adjacent to a building.

Often it is possible to store library materials and other artifacts on open shelving for long periods of time by enclosing them in ziplock or polyethylene, heat-sealed bags. As long as the item going into the bag does not have a high moisture content, the threat of mold within is minimal. The polyethylene bag acts as a buffer to temperature and humidity extremes in the room. No insects of importance to collections will chew their way into a bag to lay eggs on the item. Not only will bagging prevent insect attack, but it will also keep the item in a dust-free environment. If infestation were to be inadvertently bagged with an artifact, the polyethylene bag would contain the spread of the insects to other parts of the building.

APPLICATION OF INTEGRATED PEST MANAGEMENT TO LIBRARY, ARCHIVAL, AND COLLECTION PEST PROBLEMS

SURVEYING THE PEST PRESSURES ON THE STRUCTURE AND COLLECTIONS:

Inspections for and evaluation of possible insect infestations and other visible pests in library and archival storage areas and collections have become more important in

recent years as Integrated Pest Management (IPM) has moved to the forefront. This approach, with its movement away from purely chemical control measures, makes the inspection a cost-effective method within an integrated program.

The inspection of a facility or incoming collections for insect infestations or potential infestations should be routinely scheduled as a part of the total IPM program. Members of the Pest Control Committee must maintain vigilance in looking for insects, insect harborages, improper storage, mold, and other situations conducive to insect survival and reproduction. Minimal training will qualify personnel to perform these inspections. These individuals must be familiar with pests of libraries and collections, their habits, and the dangers posed to the collections. Recognition of such threats can then be brought to the attention of the committee for appropriate action.

Preplanning

Inspection personnel should be completely familiar with the layout of the facility. Floor plans are helpful for conducting inspections so that no areas of the structure are omitted from the inspection. The inspector must insure that he or she has keys for every closet and storage room or area of the structure. Pest problems often begin in areas not frequented by library personnel.

Proper Equipment

Copies of floor plans should be utilized for taking notes as the inspection proceeds. Pencil should be used for note taking. A flashlight with fresh batteries that throws a strong spot or beam of concentrated light is essential. A small screwdriver is helpful for opening access panels and digging into cracks and crevices. Small screw-cap viles filled with alcohol may be used for collecting specimens.

The Inspection

The inspection of the facility should begin on the exterior. Careful attention should be placed on locating insect and rodent harborages as well as those areas that act as highways into the building for vermin. Doors, windows, freight docks, garbage receptacles, screening, lighting, discarded debris, and structural integrity should be noted in the inspection.

Inspection of the interior should follow a logical flow from the time materials enter the building until they are stored or displayed. Equipment, light fixtures, shelving, cabinetry, overhead ledges, cracks and crevices, fire hoses, air filters, window ledges, wall-floor and wall-wall junctions, floor drains, corners, closets, mechanical rooms, and elevator shafts should be inspected. During the interior

inspection rodent traps and glueboards can be updated and replenished. At the same time vending machine areas, garbage disposal and trash containers, eating facilities and kitchens, and food storage areas may also be inspected.

Reporting

The inspector should give a verbal report at the conclusion of the inspection and follow this with a short written report of findings and recommendations. Copies of this report should be given to maintenance directors, collection curators, and the food-service department to insure that recommendations are carried out. The Pest Control Committee will then oversee the implementation of the recommendations. These inspections and reports should be carried out at least every 6 months, or more frequently as pest pressures dictate.

INITIATING AN INTEGRATED PEST MANAGEMENT PROGRAM

Not all facilities will have the same kinds of pest pressures on the structure and collections. To detail IPM prevention and control procedures more specifically, many will be itemized for specific pest problems as they may be encountered.

Silverfish. - Control and prevention of silverfish damage to library materials can be effected in a variety of ways:

1. Thorough vacuuming of the perimeters of rooms where silverfish like to hide beneath the toe moldings and baseboards during the daytime.

2. Use of insect sticky traps or glueboards in areas where silverfish seem to be a problem. Each night, when silverfish are active, they will be trapped on the glueboards.

3. Use of silica gel in a finely powdered form in the void space beneath the bottom shelf or drawer of storage cabinets. A 1/4-inch drill may have to be used to gain access to the voids beneath the cabinets. Silica gel is a desiccant and kills silverfish by drying them out. If silica gel powder (sometimes in combination with Pyrethrum insecticide) is placed beneath the cabinets, silverfish can't crawl up into the cabinet without encountering it, thus being repelled or killed.

4. Use of insecticide resin strips in enclosed spaces, particularly in manuscript, rare book, and print collections. Insecticide resin strips contain the

insecticide Vapona (DDVP). This material volatilizes from the resin strip and fills a confined space with molecules of insecticide. It is a mild fumigant and in time will kill all stages of insects within the enclosed space. The normal rate of application is one strip per thousand cubic feet of space.[1/] This type of chemical application is for enclosed spaces only, such as cabinets, vaults, and small storage rooms, and is not designed to be used in open, public spaces or where ventilation would carry the fumes out of the space.

5. Application of residual, liquid insecticidal sprays to perimeters of rooms and at the base of all stack shelving areas, paying particular attention to the crevice where the floor meets the wall and baseboards.

6. Crack and crevice injection of small spot applications of liquid insecticides to the backs of cabinets where they are attached to walls.

1/ The No-Pest Strip is the only dry strip available on the market today. It is available through Kenco Chemcial Company, P. O. Box 6246, Jacksonville, Florida, USA, 32236, (904) 359-3080.

7. The control and elimination or moisture such as leaky plumbing, around laundry areas, in bathrooms, and workrooms where a silverfish population can thrive because of the high moisture situation.

8. Reduction of potential sites of harborage by the use of caulking compounds and patching plasters.

Bookworms. - Control of bookworms in a library can be effected with a combination of approaches. An IPM approach would be:

1. Screen all entries from the exterior to prevent beetles from flying into the building.

2. Do not allow dried flower arrangements in the library. They often import eggs and larvae into the library. The larvae will consume the dried vegetable matter of the arrangement as well as the glue that generally holds the flower arrangement together.

3. Do not allow spices or other leafy vegetable matter to be stored in the library. Cigarette beetles are particularly fond of red spices, such as cayenne, paprika, and chili powder.

4. Do not encourage the storage or display of botanical collections in the library. If a collection is to be stored or exhibited within a library, it should be disinfested by heating to 130° F for 3 hours, to kill all stages of cigarette beetles in the sheaves of the specimens. After treatment stored collections should be housed in cabinets with Vapona resin strips to prevent possible reinfestations. Botanical specimens should be displayed in plexiglas enclosures to keep insects out.

5. To disinfest an entire structure of insects, heat the space with commercial gas burners. This approach has been successful in the past and is being used today by large cereal grain processors. All insect stages can be killed if the heat is distributed throughout the building with electric fans and a temperature of 140° F (60° to 63° C) is maintained for 6 hours. Loosen the books and materials to allow the air to circulate around them. This technique not only controls cigarette beetles in books, but all stages of insects in the entire structure (Cressman 1935).

6. Use plants that are preferred by gravid female cigarette beetles to control infestations. Whole leaf tobacco plants, for example, can be placed in strategic locations in an herbarium to act as bug traps. As the plants become infested with eggs and larvae, they can be removed and burned before the larvae have a chance to pupate and emerge as adult beetles (Merrill 1948).

7. If a localized, limited infestation is found in a library, isolate the infested books and subject them to a heat treatment. By placing the books in a standard oven at the lowest temperature possible (130° F for 3 hours) and placing wet newspaper or a pan of water in the bottom of the oven to maintain humidity inside the oven chamber, all stages of this insect, and in fact any insect, will be killed. This technique is commonly used in herbarium collections in various parts of the world. It is much easier to kill all stages of insects with heat than it is by freezing. If a source of humidity is supplied in the chamber, the books should not dry out during treatment. Only active infestations should be treated in this manner. Dark exit holes that have no powder associated with them indicate that the

infestation has long since died out and does not require treatment.

8. If a library has an active bindery, sometimes it is possible to mix a pesticide with the glue as the damaged books are bound. In some parts of the world, the insecticide dieldrin is used for this purpose. A cigarette beetle larva consuming some of the glue would then be killed before it has a chance to develop and emerge as an adult beetle.

9. Eliminate pigeons' nests from the building. In one instance, drugstore beetles were emerging from pigeon nest debris and gaining access to a library through loose-fitting windows. The larvae of the beetles were feeding on undigested grain and other food products found in the manure layers of the pigeon nests.

10. Use fans to keep air circulating in the stacks and to keep the books dried out as an aid in controlling infestations. Attempt to keep moisture levels between 50 and 60 percent relative humidity at all times.

11. Inspect the stacks regularly with a flashlight to pinpoint areas of infestation by locating the piles of fine powder drifting from the books onto the shelving.

Cockroaches. - Integrated Pest Management approaches to the control of the large species of cockroaches include:

1. Installation of a gravel 4-foot barrier around the perimeter of the library to prevent ingress from outdoors.

2. Elimination of all vines and ivy from the building.

3. Installation of proper screening for all windows and doors.

4. Installation of exterior lights so that they will shine on the building from a distance rather than being fastened to the building and attracting insects during the night to the exterior walls of the building.

5. Removal of all debris, leaves, and twigs around the exterior of the library as well as cleaning out debris from gutters on the roof of the building.

6. Elimination of cockroach harborages and entries by caulking and sealing.

7. Installation of sticky glueboards which will trap insects on their nightly forays around the library. These insect traps can be installed in false ceilings, basements, elevator shaftways, and closets to intercept insects as they travel looking for food.

8. Use of insect baits, such as 2% Baygon Cockroach Bait, applied sparingly to quiet zones of the interior of the library. This bait, which looks like sawdust, is bran mixed with molasses and contains 2% Baygon. It is a favorite of large cockroaches and will easily bring populations into control.

Whenever insect infestations are found, a common attempt at their control is by insecticidal treatments with an aerosol or fog. Insecticidal fogs or aerosols should never be used in any collection.

Such formulations are oil-based. During application small droplets of the oil-insecticide mixture are dispensed into the air and will eventually settle on the entire collection. This kind of treatment irreversibly damages collections.

9. Perimeter fan spraying with residual insecticides, paying particular attention to those areas adjacent to pipe chases, elevator shafts, storage areas, and mechanical rooms. In the case of the American and Australian cockroaches, perimeter, exterior power-spraying of the walls and overhangs may be required, particularly in tropical zones.

10. Installation of thresholds and rubber flaps on exterior doors to prevent ingress by cockroaches from the exterior, particularly at night.

11. Use of copper wool in holes and openings leading from drainage and sewer systems to prevent cockroach ingress.

12. Use of fiberglass insect screening for basement and first floor level floor drains to prevent cockroaches from entering the building via the sewer system.

Psocids or Booklice. - Control of booklice is difficult. Several approaches must be considered.

1. In enclosed spaces a Vapona resin strip may be used to control psocids.

2. Lower the moisture in materials and in the room to prevent mold growth. The use of fans and climatic controls to keep the relative humidity within a range of 50 to 60 percent and temperature from 68° to 72° F will aid in reducing psocid populations.

3. For archival materials in "dead storage" place the material in a large polyethylene plastic bag with several cups of dried, powdered silica gel wrapped in muslin or cheese cloth. Moisture within the bag will be lowered to the point where mold will not grow and psocids will be eliminated.

4. Use paradichlorobenzene (PDB) as a fumigant to control book lice in heavily infested, moldy books. A very tightly confined space must be used, such as a weather stripped cabinet or closet or a heavy-duty polyethylene bag, and sufficient quantities of PDB crystals to obtain air concentrations that will

effectively kill the insects. A rate of one pound of crystals per one hundred cubic feet of space for a period of at least 2 weeks is the minimum necessary for complete kill. Paradichlorobenzene used in this manner will also kill surface mold and spores on the materials. After fumigation the materials should be aired thoroughly.

Carpet Beetles and Clothes Moths. - Control of carpet beetles and clothes moths is not difficult provided the staff is involved in the IPM program. Such measures are:

1. Thorough vacuuming on a regular basis of all library areas paying particular attention to the edges of the room where adults find dead insects on which to deposit their eggs. Biannual inspection and vacuuming of false ceilings, attics, closets, maintenance areas, mechanical rooms, and elevator shaft pits are necessary to eliminate reservoirs of food sources and carpet beetle larvae.

2. Placement of sticky traps to intercept insects as they crawl into the library helps to keep carcasses of insects at a minimum. Keep in mind, however, that carpet beetles can fly into a sticky trap, lay

eggs on a dead insect, and fly out of the trap without being trapped themselves. The larvae can proceed to devour the carcass of the insect on the sticky trap, pupate, emerge as an adult beetle, and fly out of the trap without being mired in the glue of the trap. This situation necessitates the removal of traps, with an accumulation of insects, on a regular basis and replacement with a fresh trap.

3. Screening of all windows and doors to prevent ingress of adult beetles from the exterior of the building. Plantings of shrubbery around the building should not include plants whose flowers are white or blue and whose flowers contain high amounts of pollen. Crepe Myrtle and Spiraea are very attractive to adult carpet beetles, where they feed on pollen.

4. Elimination of all birds' nests on and around the building. Carpet beetles become entrenched in such nests, where they feed on dead birds, feathers, and other debris.

5. Elimination of rodents and rodent nests for the same reasons given in number 4.

6. Use of residual sprays may help to some extent for carpet beetle control, but are usually of little value, particularly in warm, humid climates.

7. Use of Vapona resin strips in vaults, closets, and enclosed storage spaces to eliminate all stages of carpet beetles within these spaces.

8. Use of polyethylene bags to totally enclose susceptible materials and keep fabric pests from attacking valuable items. As long as the items do not contain high amounts of moisture when placed in the bag, the threat of mold on the interior of the bag is minimal.

Subterranean Termites. - As discussed in an earlier section, the subterranean termite colony lives in the ground, and workers make their way up into the structure to feed on cellulosic materials. The key to subterranean termite control is to make a structure less conducive to their attack by physical alteration and to establish chemical barriers in the

soil through which they cannot penetrate. Chemical soil poisoning as a means of subterranean termite control should be carried out by a professional fir Physical alterations may include:

1. Elimination of all wood-ground contacts. All wooden elements including posts, stairwells, exterior ornamentation, wooden skirting, interior support posts, grade stakes, and form boards should either be removed or set on concrete bases.

2. Installation of proper guttering and grading to carry water away from the building, making it less conducive to termite invasion.

3. Insure that wood siding is at least 6 inches from the ground.

4. Insure that earthen crawl spaces are no closer to floor joists than 18 inches.

5. Removal of all debris from crawl spaces including stumps, tree roots, scrap wood, form boards, wood chips, and paper materials.

6. Insure that cellar hatchways are constructed of solid concrete, concrete blocks, or metal instead of wood.

7. Insure that frames of cellar windows be made either of metal or pressure-treated wood.

8. Insure that vent and foundation opening frames be constructed of metal or pressure-treated wood.

9. Installation of metal permanent termite shields on tops of foundations before wooden elements are secured to them.

10. Insure that all areas where pipes penetrate a slab on grade are totally encased in concrete.

Drywood Termites. - Making a building as tight as possible will help reduce infestations of drywood termites on the interior. The following actions may be helpful in preventing drywood termite attack:

1. Maintain proper screening of all windows and doors.

2. Insure that foundation vents and windows are made of materials not conducive to drywood termite attack.

3. Inspect attic vents for proper screening.

4. Insure that the roof line where the exterior wall meets the roof is tight to prevent drywood termite ingress.

5. Provide proper lighting on the exterior as discussed in a previous section.

Mice. - Mouse control in a library is important and should be dealt with in the following ways:

1. Seal the building on the exterior as tightly as possible with copper wool and caulking compounds.

2. Never use a toxic baiting program for mice on the interior of a library. The mice will die in the walls, floors, and ceilings and provide food for carpet beetles.

3. Use mechanical control techniques. Snap traps baited with cotton balls smeared with peanut butter can be used to trap mice. Multiple-catch live traps are available on the market, such as the "Ketch-all" trap. These are capable of catching more than one

mouse at a time without the use of bait, relying on the innate curiosity of the mouse. Glueboards can also be used to trap mice. Soon after they are trapped they will die, and the glueboard can then be discarded.

4. Inspect the building thoroughly with a flashlight on a periodic basis to identify those areas where mice are present. The presence of droppings is a clear indication that control measures should be undertaken in the exact spot. Two or three weeks after a control program has been instituted, remove all droppings so the progress of the trapping program can be determined.

5. In temperate regions institute trapping programs in late summer and early fall so they will be in place when the mice naturally tend to invade structures.

Rats. - Rat control is aimed primarily at the exterior of the building and may include:

1. Maintaining adequate rat bait stations on the exterior perimeter of the building.

2. Inspecting the grounds, shrubbery, and ground covers for evidence of rodent activity, such as rat burrows, runways, and droppings. Make bait placements directly into the rodent burrows.

3. Clearing debris, piles of lumber, old equipment, and other harborage sites away from the building.

4. Installing and maintaining a gravel 4-foot barrier around the perimeter of the library to prevent ingress from outdoors.

Molds and Mildew. - The following actions will be found useful in correcting mold and mildew problems in libraries:

1. An air-handling system should be installed that will drop the humidity from the air and then reheat it to desired levels. This system should be designed to handle incoming outside air as well as recirculated air. Such systems must be carefully thought out and sized to accept incoming loads with humidity levels of the exterior air as well as the amount of moisture contained in the interior air. The aim is to maintain an interior environment in the library of

from 50 to 60 percent relative humidity and 68° to 72° F at all times.

2. If such air handling systems are not available or cannot be installed, fans can be used to keep the air moving, particularly near outside walls and close to floor levels, in an attempt to lower moisture content of library materials and to eliminate pockets of high humidity.

3. Waterproofing basements and walls below grade on the exterior to prevent moisture from wicking through the walls and into the interior will aid in keeping humidity levels down on the interior of the building.

4. Earthen floors in basements and sub-basements should be sealed with concrete to prevent the wicking of moisture up into the building. At the very least, earthen floors should be covered with 4- to 6-mil polyethylene film to lessen the amount of moisture being volatilized into the interior air.

5. Water-sealant paints or epoxies can be applied to floors and walls to prevent ingress of moisture to

the interior of the building.

6. Attic vents and fans can be installed to pull air through buildings where no air-handling systems are available and where tropical climates require windows to be opened throughout the year. With such installations at least air can be kept moving throughout the building.

7. Open trenches and drains in mechanical rooms and areas adjacent to stack areas should be covered to prevent evaporation of liquid into the interior space.

8. Except for drinking fountains, interior fountains or waterfalls should not be permitted in a library.

9. Do not allow indoor planted areas in a library. Keep ornamental and hanging plants to a minimum to reduce the amount of water released into the interior air.

10. Heavy mold infestations resulting from flooding, water damage, leaks, and fires is an entirely separate topic and cannot be dealt with within the scope of this paper.

11. Regular inspection of the collections with a flashlight to pinpoint trouble areas is a necessity. Localized infestations of mold may be temporarily arrested with topical applications of chemicals until other modifications can be made.

12. Thymol is commonly used as a mold-control chemical on books, paper, and other library materials. The use of thymol, either as a mist or spray, or as a fumigant volatilized by heat, does not impart residual mold control to library materials. Thymol will kill some species of mold spores and mycelia upon contact. Taking the materials out of the atmosphere of thymol will leave them vulnerable to mold spore deposition and possible germination.

    In the United States thymol is not registered with the Environmental Protection Agency as a mold-control chemical. It is often used, however, by library technicians and museum conservators. A wet mist is applied by dissolving thymol crystals in ethyl alcohol (ethanol). A 1 percent finished dilution is normally used. The technician wears a respirator approved for organic chemicals as well as goggles when using thymol. To protect from dermal irritation, the techician should also wear rubber gloves.

Some institutions have designed small chambers for the use of thymol for fumigations. Thymol crystals are placed on a metal tray and heated with several light bulbs. The space within the enclosed chamber becomes saturated with thymol molecules, fumigating the materials in this space. The same precautions apply for the operator as previously mentioned. Goods fumigated in such a way should be aerated thoroughly in a fume hood or outdoors to volatilize any remaining thymol before the materials can be safely handled. As stated previously, after the materials have been aerated, no thymol will remain on the materials to provide protection against subsequent mold development.

Paradichlorobenzene (PDB) has been used in enclosed spaces as a mild fumigant for mold control. Where a thymol fumigation takes no more than 24 hours for the application phase, a PDB fumigation will take up to 3 weeks unless the crystals are volatilized by heat. As before, PDB does not give residual mold control to the library materials.

Ortho phenylphenol (OPP) is another phenolic chemical that has been used for nonresidual mold control on library materials. This chemical is not

registered for use for mold control in libraries in the United States, but has been used in the past for extensive mold infestations brought about by flooding and fires. Repeated applications of the diluted material in alcohol have been made by spraying or fogging this solution onto the library materials.

Repeated applications are made over a series of days. These types of applications are usually performed by professional pest control operators or those who are thoroughly trained in the use of this chemical.

Alcohol and dilute bleach solutions have been used by technicians for spot applications to library materials, shelving, walls, and floors. Any strong oxidizing agent will kill mold spores, but none will impart residual chemical control.

FIREPROOF SAFES AND FILING CABINETS

Often valuable collections and records are stored in fireproof safes and filing cabinets. These thick-walled storage containers have insulation in their walls to prevent fire from damaging the items housed within.

Two types of insulation are used for these kinds of

storage cabinets. One is a dry insulation which gives superior protection, but is higher in cost. The second type of insulation is termed a wet insulation and is generally found in lower priced, consumer safes and filing cabinets.

The most common type of wet insulation is a mixture of Portland cement, Vermiculite, diatomaceous earth, and glass fibers. During manufacture this mixture is poured between the walls of the cabinet and allowed to cure. In the curing process moisture is retained by the Vermiculite particles and the diatomaceous earth. During a fire the heat of the fire turns this moisture into steam, which is generated into the interior space of the filing cabinet or safe.

Unfortunately, often moisture is continually generated by the wet insulation and creates a very high humidity inside the safe or filing cabinet, even without a fire. These types of fireproof safes and filing cabinets continue to cure over long periods of time. In the meantime they may create severe mold problems on the goods stored within the cabinet.

Many people have found that they must leave the drawers open almost continually to prevent excessive moisture buildup inside the cabinet. This practice makes the cabinet useless as a fireproof cabinet and requires continual attention on the part of the staff. The solution to the problem is to purchase fireproof safes and cabinetry that have dry insulation and therefore do not have these problems with moisture release and high humidity.

SURVEILLANCE OF THE PROGRAM

Once the Pest Control Committee has put together its Integrated Pest Management program, routine inspections and surveillance are required to insure that the program is being carried out. If professional pest control operators have been called in to implement certain phases of the IPM program, surveillance should also be made to insure that the contract is being fully implemented and that monies are being properly spent.

The Pest Control Committee should maintain liaison with conservation and professional pest control personnel to be kept abreast of continuing developments that might impinge on the IPM program. This relationship will also enable members of the committee to remain informed about training programs and seminars germane to their efforts. The committee may also want to subscribe to various trade publications of the pest control industry in their search for continuing knowledge and training.

FINAL OBSERVATIONS ON COSTS AND BENEFITS

This study places strong emphasis on the need for library personnel to inspect, maintain, and implement measures designed to prevent pest infestation at the facility. In-house staff are intimately familiar with the organization

of the library, the layout of the facility, management of the collections, and the desire to implement common sense approaches to prevention rather than chemical control of outbreaks. With a minimum investment in training and direction, the in-house staff can put together an IPM program that meets the needs of the institution for minimal cost.

Library personnel will rely on the professional pest control industry to implement specific aspects of the program as well as to provide input into some of the technical aspects of pest prevention and control. The ultimate decision-making processes, implementation, control, and oversight of the program should be in the hands of the Pest Control Committee and library management.

LIST OF ILLUSTRATIONS

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