Managing Damage by House Mice

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Summary of Damage Prevention and Control Methods:

Exclusion:

Seal all openings larger than ¼-inch in diameter

Habitat Modification:

Proper sanitation practices reduce food, water, and shelter for mice. These include storing food items in rodent-proof containers, controlling weeds around buildings and structures, and removing accumulated debris and junk piles around buildings.

Frightening:

Standard devices are not effective in preventing damage. Ultrasonic devices have not been proven by research to be effective.

Repellents:

None registered, although moth balls (naphthalene or Para-dichlorobenzene) and ammonia in strong concentrations may temporarily work in small enclosed areas.

Toxicants:

Single-dose (acute) poisons:

- Strychnine (restricted-use pesticide, below-ground use only)
- Zinc phosphate (restricted-use pesticide)
- Cholecalciferol (Quintox, Rampage, Vitamin D_3)
- Bromethalin

Multiple-dose (chronic) anticoagulants:

- Brodifacoum (Talon, Havoc)
- Bromadiolone (Maki, Contrac)
- Chlorophacinone (RoZol)
- Coumafuryl (Fumarin)
- Diphacinone (Ramik Green, Contrax-D)
- Pindone (Pival, Pivalyn, Contrax-P)
- Prolin
- Valone (PMP, used in tracking powder)
- Warfarin (d-Con)

Fumigants:

Practical and cost-effective only in situations of severe damage in large areas containing dense mouse populations. Very hazardous, for use only by trained applicators.

Traps:

Snap traps (inexpensive, effective on small areas with few mice)
Live traps (Ketch-All, Victor Tin Cat, Sherman)
Glue boards

Other Methods:

Domestic predators (dogs and cats) have limited value in some situations.

Contents

Introduction

In the United States and other countries around the world, the house mouse (*Mus musculus*) is considered to be the most troublesome and economically devastating rodent of any species in this taxonomic category. Its ability to thrive despite close contact with humans is due to its adaptability to a wide range of environmental conditions, high reproductive rates, and diverse omnivorous feeding habits. The house mouse can survive indoors or out, with or without readily accessible water.

Damage caused by house mice can be extensive and economically significant. They inflict damage on houses and other structures; destroy personal property; and consume field crops, stored food, and fiber. Mice often leave partially eaten food. Along with food contamination from droppings and urine, considerable losses in stored foods are common.

House mice also pose potential public health problems by transmitting diseases and parasites to humans and domestic animals. Hantavirus, a viral infection causing respiratory distress syndrome (RDS), is the most notable, recently publicized disease associated with house mice.

This publication discusses the general biology of the house mouse, public health implications from disease transmission, damage problems and economic impacts, and offers suggestions for preventing and controlling damage.

Identification and Description

The house mouse is a small, agile rodent with somewhat protruding small black eyes and a semi-tapered nose. Ears are rather large and sparsely hairy. The tail is hairless, about as long as the head and body length, with visible scale rings. Adult mice weigh approximately 2 / 5 to 1 ounce. Fur colors vary from light brown to dark gray but commonly occur as a grayish to medium brown with gray or buff belly coloring.

Other mouse species commonly mistaken for the house mouse include the deer (or white-footed) mouse, jumping mouse, harvest mouse, and meadow mouse. The deer mouse is the same size or slightly larger than the house mouse but has distinct white markings on the feet, belly, and bottom half of the tail. The jumping mouse also has a distinct white belly. The harvest mouse has grooved upper incisor teeth, unlike the house mouse. Finally, the meadow mouse (or vole) is less agile with smaller ears and eyes, a shorter tail, and a chunky body almost twice the size of a house mouse.

Distribution

The house mouse is originally from central Asia. Early settlers from Europe inadvertently brought the house mouse to North America via sailing ships. The species quickly spread across the continent and is now found in every state including the coastal areas of Alaska and southern Canada. It is the most widely distributed commensal (closely associated with humans) rodent in the United States.

Habitat

House mice are found in grassy fields, cultivated grain crops, barns and other agricultural related structures, unfinished buildings, homes and offices, or other places humans occupy. They seem to prefer a moderate climate. However, they also inhabit mountainous or desert regions close to human settlements. As cold weather begins in late fall, house mice invade buildings and structures in search of shelter and food.

Food Habits

House mice prefer eating seeds, grains, and cereal food types. However, foods high in fat, protein, or sugar, such as bacon, cheese, lard, meat, chocolate, butter, candy, and nuts are also relished. They tend to be omnivorous "nibblers," taste-testing all the food items available in their habitat. These sporadic feeders nibble small amounts of food several times a day but seldom in one place. They can manage with little or no readily accessible water, obtaining most of their water requirements from the foods consumed. Active primarily at night, their two main feeding periods are dusk and just before dawn, with smaller meals consumed every ¾ to 1¼ hours.

Their preference for the germ of some cereals is probably due to the softness of this portion, which makes gnawing easier. House mice hold grain kernels such as oats and wheat like humans eating corn-on-the-cob. These small grains are easily manipulated by their front feet, although portions of the kernels are dropped as they become smaller.

General Biology

Reproduction and Nesting

House mice living outdoors breed seasonally when climatic conditions are favorable. Under these conditions peak breeding activity occurs in spring and fall. For those living indoors, or where optimal weather and environmental conditions exist year-round, breeding occurs throughout the year.

Females have five to 10 litters per year, averaging five young per litter. When mouse populations become high, breeding and survival of young decreases markedly. Environmental conditions such as food availability and quality influences reproduction and growth.

Nesting occurs where shelter and materials are available, and nests are constructed of shredded paper, burlap, fabric, insulation, or other fibrous materials. Nests resemble a woven mass, or "ball," and they are usually 4 to 6 inches in diameter. If living in a field, mice can burrow into the ground to nest.

Litters are born approximately 19 to 21 days after mating, although lactating females that conceive while nursing may have a longer gestation period. Newborn mice are hairless with closed eyes and ears. By the third week, they open their eyes and ears, eat solid foods, and make short excursions from the nest. Weaning takes place around three weeks of age with complete sexual maturity at six to 10 weeks. A summary of reproductive and development data is presented in Table 1.

Movements and Social Behavior

Movements of house mice are largely determined by habitat, climate, and food availability. When these conditions are adequate, mice will stay in a relatively small area, usually within a few feet. However, males tend to roam in a slightly larger area than females. Mice travel over their territory daily, curiously investigating any new foods or objects in their environment. This habit makes house mice susceptible to bat stations and traps.

Mice establish a "pecking order" within their social group, which leads to the establishment and maintenance of territories. Unrelated male mice are highly aggressive toward one another. Also, strange individuals of either sex are commonly met with aggression from other territorial individuals. When dominant mice are inactive, the subordinate mice become sexually active and engage in feeding activity.

Researchers believe that strong social hierarchies interfere with control efforts. Therefore, control may be more effective when started before territories are established. For example, constantly reshuffling warehouse commodities improves control efforts, probably because it disrupts established territories.

Table 1 – Summary of biological and life history on the house mouse.*

Item	Amount
Daily food consumption	0.04 – 0.11 ounces
Daily water intake	0.03 – 0.07 fluid ounces
Adult weight	0.42 – 1.06 ounces
Breeding life (females)	6 – 10 litters
Breeding life (males)	1 – 1.5 years
Gestation period	19 – 21 days
Litter size	5 – 6
Birth weight	0.02 – 0.04 ounces
Eyes open	11th day
Begins to eat solid food	11th day
Age at weaning	21 days
Age at mating	6 – 10 weeks
Breeding season	All year long
Life span	1 – 2 years

*Data from Marsh and Howard (1981)

Senses

House mice have poor eyesight and are essentially colorblind but have acute sensitivity to light variations. Their colorblindness allows baits to be dyed various colors for safety without alerting the mice as long as the dye does not have an objectionable taste or odor. House mice rely on excellent senses of hearing, smell, taste, and touch to locate food and escape danger.

Their sense of smell is used to find food and distinguish between individuals, especially those of the opposite sex. They also have good taste perception. Once a tasty food item is eaten, the associated odor becomes unimportant.

House mice use their acute hearing to avoid potential danger. Research has not supported the claims of manufacturers producing ultrasonic devices to frighten mice from houses and other buildings. Their sense of touch aids in traveling along walls and burrows in the dark. Long whiskers near the nose

and guard hairs on their bodies provide sensitive stimuli for navigating in the dark.

A series of quick, predictable movements in response to potential danger from external stimuli are sometimes called the kinesthetic sense in house mice. A sequence of predictable reflexive movements automatically occurs when muscles, tendons, and joints are stimulated by potential danger. This practiced movement pattern protects mice from danger.

Physical Capabilities

House mice have exceptional physical capabilities used for gaining entrance to houses and other structures. These include gnawing, climbing, jumping, swimming, and other techniques. The following summary of physical capabilities should be considered when implementing a damage control program.

- Jumping: Some mice can jump 12 inches from the floor onto an elevated flat surface, or jump from a height of 8 feet to the floor without injury. Walls or flat vertical surfaces are used as spring boards to reach surfaces at additional heights.
- Climbing: House mice can climb almost anything with a rough surface including wood, brick, metal girders, pipes, weathered sheet metal, wire mesh, and cables.
- Running: House mice can run horizontally along insulated electrical wires, small ropes, and other materials with narrow diameters. House mice can travel upside down on ¼-inch hardware cloth.
- Swimming: If forced, house mice can swim. However, they do not dive below the water surface.
- Other tactics: House mice are able to squeeze through openings slightly larger than ¼-inch in diameter. Breeding and survival continues in temperatures as low as 24 degrees Fahrenheit when sufficient food and nesting material are available.

Population Dynamics

Mouse densities are determined by habitat quality. Adequate food, protective shelter, amount of human activity, and weather are the primary factors affecting population size. However, in free-living populations of house mice, social stress and competition between individuals will eventually limit popu-

lation size despite unlimited availability of food and cover. When high population densities occur, intra-specific strife ensues resulting in a reduction of births, increased death rates, emigration out of the area, or a combination of these factors.

House mice are a problem because of their high fertility rates and the ability to survive under a wide variety of environmental conditions. Because mice populations can reproduce rapidly, they must be held at extremely low population levels to avoid multiplying at an uncontrollable rate. Unless the habitat is destroyed or sufficiently damaged to maintain low population levels, control measures will have to be intensive and continual to minimize damage effects.

Economic Impacts

Estimating economic losses caused by house mice is difficult especially because family heirlooms or personal possessions can not be replaced at any cost. Economic losses are greatest from items discarded due to contamination rather than from food consumed by mice. Each year, thousands of people discard family heirlooms, paintings, historic documents, and other items damaged by mice in attics and garages.

A survey conducted in one midwestern corn-growing state showed that 76 percent of approximately 1,000 corn samples were contaminated with rodent droppings. Mouse droppings outnumbered all other rodent droppings by a ratio of 12 to 1. The amount of food contaminated by mice is about 10 times greater than the amount consumed. Researchers report that in six months, one pair of mice can eat about 4 pounds of food and deposit approximately 18,000 droppings. Although actual monetary values cannot be estimated for these losses, the expense involved with discarded items is high.

Indirect economic losses due to house mice damage are also difficult to estimate. Many house fires of “unknown causes” are probably rodent-related from gnawing of electrical wiring. House mice are frequently found nesting in household appliance cabinets such as freezers, refrigerators, and stoves. Chewing into the power supply of these appliances causes damage to the appliances and loss of frozen or refrigerated food.

Total annual economic losses caused by house mice may never be known. However, the effects are experienced by both the rich and poor.

Diseases

A number of diseases transmitted to humans and domestic animals have been linked to house mice and the parasites on their bodies. These include salmonellosis, rickettsialpox, lymphocytic choriomeningitis, leptospirosis, ratbite fever, ray fungus, ringworm, dermatitis, and hantavirus, and illnesses caused by tapeworms.

Salmonellosis, or bacterial food poisoning, can be spread when the feces of infected house mice contaminate human foods. Rickettsialpox is a fever-related illness that causes a chickenpox-like rash in humans. Mites found on the bodies of infected house mice can transmit the disease after biting human hosts. Lymphocytic choriomeningitis is a viral infection of house mice that is transmitted to primarily children when respiratory droplets or fecal materials from infected mice contaminate food or dust particles.

Leptospirosis, a disease commonly associated with domestic pets, can be transmitted to humans from foods contaminated by mice and rat urine. Ratbite fever, ray fungus, tapeworms, and ringworm can also be transmitted by similar modes of food contamination. Dermatitis, causing irritated and itching skin in both children and adults, can be transmitted from mites or infected house mice. Dermatitis is frequently attributed to other causes such as heat rash, allergies, and fleas.

Hantavirus

A more recently identified life-threatening viral disease affecting humans, called hantavirus, has been linked to rodents, primarily the deer mouse, as carriers. Hantavirus causes a respiratory distress syndrome (RDS) that has resulted in the deaths of 56 people in the United States (at this writing), including one in Fremont County, Wyoming. The syndrome is characterized by fever, muscle aches, chills, dry cough, headache, nausea and vomiting, and shortness of breath. It has been fatal in more than 60 percent of known cases to date.

Although deer mice are the primary hosts for the virus, other rodents found to be carriers include house mice, rats, chipmunks, and voles. The virus is spread among rodent populations from biting one another.

Human infection occurs when dried materials contaminated by rodent feces and urine are distributed directly onto broken skin, inhaled, or possibly ingested in contaminated food or water. Infections occur primarily in adults and are associated with the following activities: 1) planting or harvesting

Hantavirus, a life-threatening viral disease causing a respiratory distress syndrome (RDS) in humans, is primarily linked to the white-footed deer mouse. This mouse species is the same size or slightly larger than the house mouse but has distinct white markings on the feet, belly, and bottom half of the tail. Unlike the house mouse, the white-footed deer mouse prefers outdoor environments and rarely ventures inside residential homes and buildings (Photo courtesy of Lyle Crosby, U.S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA-APHIS), Animal Damage Control, Casper)

field crops, 2) occupying previously vacant cabins or other dwellings, 3) cleaning barns and other outbuildings, 4) disturbing rodent-infested areas while hiking or camping, 5) inhabiting dwellings with indoor rodent populations, and 6) residing in or visiting areas in which the rodent population density has increased.

Rodents testing positive for hantavirus infection have been found throughout the United States, suggesting that this is not a new virus but rather a virus for which detection methods have only recently been developed. A 1993 survey of 12 Wyoming counties confirmed the presence of hantavirus in at least one deer mouse in the following counties: Albany, Big Horn, Campbell, Carbon, Fremont, Hot Springs, Platte, Sweetwater, and Washakie.

Although the probability of contracting the virus is extremely low, risk can be reduced further by practicing good environmental hygiene habits. Good hygiene will discourage rodents from colonizing the home and work environment. Follow these three basic guidelines to minimize risk of contracting hantavirus:

Control Rodents Indoors:

- Remove rodents with traps. Poisons are not recommended because animals may crawl off and die where they cannot be reached for proper disposal.
- If high rodent densities exist in a home, contact a pest-control professional.
- Seal, cover, or screen all openings to the outside greater than ¼-inch.
- Keep all foods in covered containers or in a refrigerator.
- Keep homes clean. Clean food spills and remove water sources that rodents might use for drinking.
- Wash dishes immediately after eating.
- Eliminate potential rodent shelters by keeping clothes picked up and removing clutter in homes.

Clean Rodent-Contaminated Areas:

- Always wear rubber or plastic gloves.
- Spray nests, contaminated areas and objects, droppings, and dead rodents with general-purpose household disinfectant. Place soaked materials in plastic bags and dispose of cleaning materials. Double-bag contaminated materials and burn or bury at least 2 feet under ground.
- Mop floors with a solution of water, detergent, and disinfectant.
- Steam-clean or shampoo carpets.
- Launder contaminated clothing and bedding with hot water and detergent, then machine dry on a high setting.

Control Rodents in Outdoor Living and Working Areas:

- Do not leave open containers of water or food for rodents to drink and eat from.
- Keep home sites free of trash, litter, junk, and other debris that may provide shelter for rodents.
- Keep animal feed and grains in rodent-proof containers and store them at least 100 feet from homes.
- Keep wood piles and similar items that may provide shelter for mice 100 feet or as far away from homes as possible.

Legal Status

House mice are not protected by law and therefore may be controlled using mechanical traps or pesticides. Pesticides must be registered by federal or state authorities for the purpose of killing mice.

Damage Problems and Identification

Damage problems associated with house mice include both direct food consumption and contamination. They can be a problem on farms, in feed storage structures and mills, warehouses, bakeries, markets, homes, or other places where food storage occurs. House mice also cause considerable damage to containers and packaging materials. Their habit of sampling food and simultaneously contaminating it with feces and urine results in more food destroyed than consumed.

Mice living outside near agricultural areas can ruin field crops by digging up and eating newly planted grain. They can also cause additional damage to grain crops prior to harvest. However, these losses are insignificant compared to the damage inflicted on stored grain and food.

House mice can also cause extensive structural damage to homes and other buildings. They gnaw to gain access into buildings while nest-building activities damage insulation in walls and attics. In large appliances, they use insulation for nest building and chew on wiring, which commonly results in short-circuits or other malfunctions. Stored family heirlooms in attics, basements, garages, or museums may also be damaged by house mice.

Detecting Mouse Presence

Presence of house mice can be detected from a number of different evidence signs or "calling cards." These include the following:

Droppings: The presence of droppings or feces is usually the first clue of house mouse infestation. These are found along pathways, in nesting areas, or feeding sites. Mouse feces can be easily confused with droppings from certain insects such as cockroaches, and bats. Mouse droppings are about ¼-inch long, compared to cockroach droppings of 1/8- to ¼-inch long. Bat droppings contain insect fragments and are more easily crushed between the fingers. After a few days mouse droppings become quite hard.

Tracks: Tracks are hard to spot. Look for tracks or tail marks on dusty surfaces or muddy areas. Some people place nontoxic tracking dust such as flour or talcum powder on suspected runways overnight and look for tracks in the morning.

Urine: Urine stains may occur where droppings are found, especially on well-used pathways. Under ultraviolet (black) light, urine stains will fluoresce. Sometimes house mice will make "urinating pillars," which are small mounds of grease, urine, and dirt. In places where mice have lived for a long time these pillars become conspicuous.

Smudge Marks: These rub marks are left along pipes, beams, rafters, and walls where mice constantly travel. The oil and dirt on mice fur rubs off on these structures along frequently traveled routes, leaving stains. However, smudge marks are not easy to spot.

Gnawing: Teeth marks are left on baseboards, doors, basement windows and frames, kitchen cabinets, stored materials, and wall material. Additional evidence of their presence is obvious coarse sawdust-like material that remains after mice gnaw an opening. Mice often gnaw at small cracks beneath doors and along walls to gain entry. Entry hole sizes are usually 1½-inches in diameter or smaller for mice, and 2-inches or larger for rats. Because their paired incisor teeth grow continually, mice need to gnaw on hard surfaces to keep the incisors worn down.

Sounds: Although muffled and faint, sounds from gnawing, wall climbing, running across upper surfaces of ceilings, clawing, and squeaks are common where mice occur.

Visual Sightings: Sightings during the day are uncommon, although mice are more often seen during the night. A powerful flashlight at night can help spot mice in a large room or warehouse.

Nests: Nests are easily identified by the presence of fine, shredded fibrous material or paper. They are commonly found when cleaning garages, barns, attics, basements, and storage areas infrequently used by humans.

Odors: A characteristic musky odor indicates the presence of mice.

Excited Pets: Cats and dogs may scratch and paw at kitchen cabinet doors, refrigerator bases, stoves, walls, and other areas with mice.

Estimating Mouse Numbers

Estimating the number of mice in a house or other building is difficult. A few simple methods can be used to get an idea of the degree of infestation in terms of low, medium, or high. These techniques will not provide exact population estimates but rather an estimate of mice densities.

A fairly simple method of assessing mice density is to evaluate the number of tracks in small areas of scattered flour, powdered chalk, corn starch, or talcum powder. Several patches of these "tracking-dust" materials can be spread at 20 to 30 feet intervals throughout the structure. The size of the population can be estimated by the number of patches showing tracks and the number of tracks in each patch. Because mice do not wander far from their nests, the percentage of patches showing tracks is a good indication of population size and extent of infestation. After control measures have been implemented, compare "before-and-after" tracking patches to determine the control efficacy.

Snap traps are another fairly inexpensive and simple way to determine population size. Relatively speaking, the more mice caught per traps set during one or more nights is an indication of population size. For example, if 10 traps are set each night for a week (10 x 7 = 70 "trap nights") and two mice are caught, trapping success is 2.9 percent (2 / 70 = 2.9 percent). In comparison, if 10 traps are set each night for a week and 30 mice are caught, trapping success is 42.9 percent (30 / 70 = 42.9 percent). In this example, house mouse populations are much larger in the second situation. This method provides an opportunity for broad evaluations of mouse densities.

Damage Prevention and Control Techniques

Controlling house mice densities and reducing damage is difficult with established populations for several reasons. Mice can access very small openings, making rodent-proofing difficult. They have small home ranges, or areas of travel, and require little free water, both of which make trapping and poisoning difficult. Their high reproductive capabilities and low sensitivity to anticoagulant rodenticides offer more challenges to reduce mice populations. These characteristics must be considered when implementing an intensive control program.

In areas where rat control practices are implemented, subsequent increases in the mouse populations should be expected. Habitats suitable for rats are exceptional for mice. Mice often colonize areas previously occupied by rats

and reproduce rapidly. Appropriate control measures for mice should be implemented following rat control.

There are three primary strategies for effectively preventing and controlling house mice damage. These are: (1) making homes or other buildings rodent-proof, (2) maintaining proper sanitation, and (3) reducing populations after infestation by trapping or poisoning. Rodent-proofing and sanitation are effective preventative measures. However, after mice infestations occur, some form of lethal control is almost always required.

Rodent-Proofing

Exclusion

Preventing mice from gaining access to homes and buildings is the best way to avoid damage problems. Exclusion is an important and often overlooked preventative measure for managing potential house mice damage.

Mice can squeeze through very tiny holes. In fact, damage control specialists recommend sealing all holes larger than ¼-inch in diameter. Gaps or cracks may occur in walls or door frames of a new structure as the green wood dries. Punctured screens, broken floor-drain plates, broken windows, and cracked or chipped concrete under doors are examples of places where mice can gain access. In addition, water pipe, electrical wire, telephone wire, sewer pipe, drain spouts, and vent openings should be carefully sealed to prevent entrance.

Preventing mice from gaining access to homes or buildings is an important and often overlooked preventative measure to avoid damage problems. Holes occurring in outside building walls should be sealed with gnaw-proof materials such as concrete, galvanized sheet metal, hardware cloth, coarse steel wool, or silicone caulking.

Mice commonly gain access to residential buildings through improperly sealed garage doors where inadequate or deteriorating weather stripping material exists. All doors, windows, and screens should fit tightly to "mouse-proof" a building.

Materials used to seal openings should be gnaw-proof. These can include concrete, galvanized sheet metal, heavy-gauge hardware cloth, coarse steel wool, and silicone caulking material. All doors, windows, and screens should fit tightly. Once a building is "mouse-proofed," residents should make annual inspections to locate and seal any new openings for potential mouse access.

Proper Sanitation

Habitat Modification

Scrupulous sanitation practices will not eliminate house mice but will discourage their invasion and establishment in a building. Proper storing and handling of food, cooking ingredients, animal feeds, and garbage will limit the availability of potential mouse food, thereby reducing mouse populations. Good housekeeping practices also increase the effectiveness of traps and baits because there is less available food for mice. Keeping homes and buildings clean also permits easier detection of mice presence from droppings, nests, and gnawing residue.

Mice are opportunistic, taking advantage of even the smallest amount of available food. For example, they will colonize unfinished houses and buildings, surviving off the crumbs left by workers during lunch breaks. Crawl spaces behind kitchen cabinets and appliances usually contain enough food scraps for mice, even in the neatest of kitchens. Pet food, grass seed, and

Meticulous sanitation practices that discourage invasion and establishment of mice in garages and buildings is another strategy for preventing damage problems. Eliminate messy junk piles in garages and homes that provide attractive habitat for mice. A clean garage or home also permits easier detection of mice presence from droppings, nests, or gnawing residue.

other edible items left in sacks and stored in a garage or basement are easy targets for mice. For this reason, mice are hard to eliminate from places where food is eaten, handled, or stored.

Potential mice foods should be stored in rodent-proof containers or rooms. Food materials kept in bulk storage should be stacked on pallets in a manner that allows easy inspection for mice damage and / or presence. Remember that mice can jump 12 inches from a flat surface and are excellent climbers on any non-slick surface.

Avoid storing food items near interior walls. Consider painting a white band about 12 inches wide along the floor next to interior walls to detect house mice droppings easier and as a reminder to avoid storing food items near the walls. Keep floors swept to help detect fresh droppings.

Keep exterior walls of homes, buildings, and structures free from weeds, piled debris, and stored materials. Wood piles, hay bales, and heavy brush offer attractive shelter to mice. Regular mowing and trimming of grass and weeds eliminates protective cover for mice. Placing a strip of heavy gravel around the foundation of buildings may discourage rodent digging and burrowing.

Wood piles, hay bales, piled debris, and unmowed grass and weeds next to exterior walls of homes and buildings provide attractive shelter for mice. Eliminating these habitat areas will reduce the potential for invasion and subsequent damage problems.

Non-Lethal Control Methods

Frightening Devices

Unnatural sounds made by frightening devices such as tin pie plates, whistles, bells, recording devices, and others are not effective in discouraging house mice. Mice quickly adapt to the unfamiliar sounds.

In the past, manufacturers produced devices creating ultrasonic sound and claimed effectiveness in reducing rodent damage. However, scientific research has verified that ultrasonic sound does not force house mice out of buildings or cause mortality in high populations.

Unnatural sounds, both ultrasonic and normal, will frighten house mice for a few minutes to a few weeks, but the effect is not permanent or even longlasting. Sounds are very directional and of limited distance, thus creating voids in an area inhabited by house mice. In addition, house mice learn quickly that unnatural sounds will not cause life-threatening injury. For these reasons, frightening devices are not considered effective in reducing house mice damage.

Repellents

There are currently no effective repellents on the market registered by the Environmental Protection Agency (EPA) for controlling house mice. However, moth balls (naphthalene, Para-dichlorobenzene) or ammonia used in sufficiently strong concentrations may temporarily discourage mice from enclosed areas. Chemical repellents seldom work as a practical solution to reduce house mice infestations. Methods of exclusion or "mouse proofing" and population reduction are more viable, cost-effective approaches to solving damage problems.

Lethal Control Methods

There are two types of rodenticides: single-does (acute) and multiple-dose (chronic) poisons. Single-dose rodenticides are fast-acting poisons preferred: (1) in situations requiring quick reductions of large populations, (2) when anticoagulant baits cannot be kept fresh due to high moisture conditions, or (3) where mice will not consume baits treated with multiple-dose poisons. Many multiple-dose poisons require consumption over several days for effective control. Single-dose poisons can be hazardous to both non-target species and the applicator. Many are classified as "restricted-use pesticides," requiring trained and certified personnel for application. Many house mice develop "bait shyness" or "poison shyness," a learned behavior to avoid poisoned bait. This is common when inadequate poisoning occurs on the first baiting attempt and another attempt occurs within six months. For this reason, avoid using the same single-dose poison more than two times a year on the same mouse population. Prebaiting, or setting out unpoisoned bait prior to using a single-dose poison, usually eliminates bait and poison shyness.

Multiple-dose rodenticides are usually anticoagulant formulations that cause the blood to lose its clotting ability when ingested over several days. These slow-acting poisons cause internal bleeding and subsequent death about four or five days after the first consumption. Bait shyness is usually not a problem with anticoagulants because death or sickness does not occur immediately after ingestion. Anticoagulants are safer than single-dose rodenticides because of their slower action and the availability of antidotes for accidental ingestion by humans and pets. When accidental ingestion by pets or humans occurs, antidotes such as blood transfusions or Vitamin K1 can be administered to neutralize the poison.

When using any type of rodenticide, read the product label thoroughly before using to ensure safe application. Registrations and use of rodenticides

are reviewed and revised each year. Because products are often changed or cancelled for certain uses, applicators must take responsibility for knowing about these changes.

Safety Considerations

Proper precautions must be used when handling poisons. All rodenticides should be clearly labeled "POISON" and marked with a skull and cross bones. Use a respirator or dust mask to avoid inhaling the chemical dust when mixing baits. Wear rubber gloves and an apron to prevent sink contamination while mixing and handling poisons and baits. Mix poisons in a well-ventilated room with no strong air currents, or use a fan to keep the air moving in a safe direction.

When mixing poisonous baits, faces should not be touched with hands or utensils. Do not eat, chew tobacco or gum, or smoke while mixing poisonous baits. After mixing, wash mixing equipment, gloves, and hands with soap and water. Store all materials associated with rodenticides in separate rooms or cabinets used only for that purpose. Excess poisonous baits not used should be stored in locked cabinets or rooms. DO NOT leave any rodenticide, poisoned bait, or mixing paraphernalia in the reach of children, animals, or irresponsible people.

When setting out bait, keep children and pets away from baited areas. It may be necessary to use bait boxes for both prebait and toxic bait.

Single-Dose Poisons

There are four single-dose poisons currently available for controlling house mice. They include zinc phosphide, strychnine, cholecalciferol (Vitamin D_3), and bromethalin. Zinc phosphide and strychnine are restricted-use pesticides. These rodenticides have declined in popularity for controlling house mice and are being replaced by newer, safer, and more effective anticoagulants. However, in large areas infested with these rodents, single-dose toxicants are usually more cost-effective.

Following is a brief description of the currently available single-dose poisons:

Zinc phosphide

Available in concentrates and ready-to-use dry baits, zinc phosphide is a heavy, dark gray powder, is insoluble in water, and has a strong garlic-like odor attractive to rodents. This restricted-use pesticide is one of the slowest-acting single-dose poisons. Bait-shy mice may avoid it. Oils and fats are commonly mixed with zinc phosphide to increase absorption when ingested.

Strychnine
Strychnine is a single-dose, restricted-use pesticide that seems to work well on mice that reject other baits. Canary grass seed and other dry baits are typically used as carriers. Extreme care must be taken when handling strychnine as it is toxic to most birds and mammals. In fact, strychnine has the highest potential for secondary poisoning of non-targeted animals. Strychnine is only allowed for below-ground applications.

Cholecalciferol (Vitamin D_3)
Depending upon dosage levels, cholecalciferol can be used as a single- or multiple-dose rodenticide. At high concentrations, a single feeding causes death in three to four days. Once a lethal dose is ingested, house mice cease further feeding activities. Bait shyness does not occur because the toxicant is slow acting.

Bromethalin
Bromethalin is a slow-acting poison does not cause bait shyness or require pre-baiting to be effective. However, it must be used with care as it is toxic to many non-target animals.

Single-dose poisons are generally placed for only one or two nights. After this period, remove all uneaten bait to avoid poisoning non-target animals. Dead mice that are found after poisoning should be buried or incinerated. As with any poisons, follow label directions carefully when applying.

Multiple-Dose Poisons

There are a number of multiple-dose poisons registered for controlling house mice. All of these rodenticides contain an anticoagulant that interferes with blood clotting, which causes death from internal bleeding and capillary damage. Mice killed by anticoagulants may display losses in coloration of the skin, muscles, and internal organs with areas of internal hemorrhaging.

There are two major groups of anticoagulants based on chemical structure: hydroxycoumarins and indandiones. Hydroxycoumarins include warfarin, coumafuryl, bromadiolone, and brodifacoum. Diphacinone, valone, pindone, and chlorophacinone comprise the indandiones. With the exception of two fast-acting anticoagulants, bromadiolone and brodifacoum, multiple feeding periods over several days are required to produce death.

Anticoagulants are preferred over single-dose poisons in controlling house mice for several reasons. They are readily ingested by mice, are easy to apply, do not cause bait shyness, and are relatively safe around livestock, pets, hu-

mans, and other non-target animals when used properly. In addition, the potential of secondary poisoning to scavengers and predators feeding on poisoned mice carcasses is relatively low.

Because all multiple-dose poisons work in the same manner, instructions for application are fairly consistent. Labels instruct users to keep a constant supply of bait available for at least 15 continuous days. This ensures that all mice have an opportunity to ingest a lethal dose.

Following is a brief description of currently available multiple-dose poisons:

Bromadiolone and Brodifacoum (trade names include Maki, and Contrac, and Talon, and Havoc, respectively).
Compared to the other anticoagulants, these two potent rodenticides can cause death from a single feeding. However, a period of four or five days is still required after ingestion for most deaths to occur. Because an animal can consume a lethal does in one feeding, these poisons are considered slightly more dangerous to non-target animals than other anticoagulants. Even with accidental ingestion by non-target animals, there still is enough time to administer an antidote before death occurs.

Chlorophacinone (RoZol) and Diphacinone (Ramik Green, Contrax-D)
These two anticoagulants are similar in potency to bromadiolone and brodifacoum, but they require multiple feedings to control a mouse population.

Warfarin (d-Con and other trade names) and Coumafuryl (Fumarin)
Warfarin was the first commercial anticoagulant developed. This widely used chemical is very effective on house mice, but it can cause bait shyness due to contaminants in the chemical. The encapsulated form of warfarin reduces bait shyness and is more effective. Coumafuryl is similar to warfarin with equal effectiveness.

Pindone (Pival, Pivalyn, Contrax-P)
This poison is considered less potent than chlorophacinone or diphacinone but similar to warfarin in effectiveness. The advantages of pindone are resistance to mold growth and attractiveness to insects.

Prolin
This poison is comprised of warfarin and an antibacterial agent, sulfaquinoxaline. The antibacterial agent was added to reduce the number of Vitamin K-producing microbes in the stomachs of rodents, thereby increasing the absorption of warfarin. Prolin was developed to enhance the effectiveness of warfarin, although actual results are hard to verify without independent laboratory trials.

A commercial, commonly used multiple-dose poison used for controlling house mice is d-Con. This product contains the first commercially developed anticoagulant called warfarin, which causes death after ingestion from internal bleeding and capillary damage. Anticoagulants are preferred over single-dose poisons because they are readily ingested by mice, are easy to apply, do not cause bait shyness, and are relatively safe around livestock, pets, humans, and other non-target animals.

Valone (PMP)
Primarily used as a poison in tracking powder, valone is relatively unpalatable. Theoretically, house mice will ingest lethal doses of valone after grooming themselves with tracking powder picked up on their feet or body hair. This poison is very inexpensive.

Mice can acquire a resistance to most anticoagulant chemicals when they are used over long periods at the same location. Mice with less sensitivity to anticoagulants will continue to reproduce while other mice with more sensitivity will die from poisoning. Eventually, the mouse population will be comprised of individuals resistant to most anticoagulants. However, bromadiolone and brodifacoum seem to be the only anticoagulants that mice have not yet developed a resistance to. These two anticoagulants are also effective on mice already resistant to other multiple-dose poisons. If effective control cannot be achieved with any anticoagulant, single-dose poisons can be used on anticoagulant-resistant mice.

Reasons for Failure of Anticoagulants

Resistance to anticoagulant baits is probably the least likely reason for failure in controlling mouse populations. There may be several other explanations for poor control with both “highly accepted” and “poorly accepted” baits. Following is a summary of possible reasons for poor control of mouse populations when using anticoagulant baits.

Highly Accepted Baits:

- The bait is not available for a long enough time.
- Not enough bait is available for the population size. All the bait is consumed from one baiting period to the next.
- Bait stations are too few and some distance apart from each other. Stations should be no more than 6 feet apart in active mouse areas.
- Bait stations are not placed over a large enough area, allowing mice to move in from nearby areas.
- Some mice may be genetically resistant to anticoagulant baits. Although unlikely, mouse populations can develop resistance to anticoagulants when this type of poison is used for extended periods. Suspect this reason if the same amount of bait is taken for a number of weeks without noticeable declines in mouse populations.

Poorly Accepted Baits:

- Bait is not a good choice, or it is improperly formulated. In this case, mice prefer to eat other available foods.
- Bait stations are located in low activity areas so mice prefer to eat more conveniently located foods.
- An overabundance of other food is available for mice to eat.
- Bait has become unpalatable due to mold, spoilage, or insect infestation. Replace unpalatable bait with fresh material.

Sometimes mice seem to initially accept bait well, and a population reduction occurs. However, sometime after the initial reduction, bait acceptance stops. The remaining mice probably never accepted the bait in the first place due to the formulation or location of the placement. If this happens, use another bait and relocate bait stations to different areas. If mice reduction still does not occur, use other control methods such as traps.

Bait Selection and Formulation

Grains and seeds are the best choice for baiting mice. Ground and rolled wheat, rolled barley, ground or rolled milo, corn meal, and oatmeal all work well for attracting mice. The best seed to use is whole canary grass seed (*Phalaris canarienses*). Avoid using old or moldy grains and seeds for bait. Generally, fresh, high-quality grains and seeds attract the greatest number of mice.

Bait selection should be determined by food items mice are currently eating. Baits will be more effective when current food items can be removed. When their existing diets are unknown, set up a "bait choice test" to determine bait preferences. This test can be especially cost-effective when planning to use expensive fruits or vegetables for bait. Place ½-ounce of each bait type about 4 inches apart in each future bait station location. Check the baits the next day to determine which one mice found most desirable. This strategy will save frustration and provide better results.

Mixing bait to attain the correct ratio of poison-to-food material, and adding proper amounts of sugar, oil or fat, and other attractive ingredients is difficult for the novice. For those with limited experience in bait mixing, it is best to consult with a professional rodent-control specialist. Professional control experts add substances to make baits more attractive to mice. These include fat or vegetable oil, powdered sugar, powdered milk, or cocoa. For example, ground cereal grains are often mixed with 5 percent powdered sugar and 3 to 10 percent vegetable oil.

After the bait is mixed, a lethal amount of toxicant is added but not enough to cause bait shyness. Some single-dose poisons and anticoagulants can be bought in concentrate form for mixing baits.

Ready-To-Use Baits

There are several types of commercial ready-to-use baits available; most contain anticoagulants. These baits are safer because the applicator does not have to handle the rodenticide in its concentrated form. Following are some examples of ready-to-use baits and a description of their use for specific situations.

Grain-Based Bait:

These are available as a loose meal or in pelleted form, in bulk, or packaged in small paper, cellophane, or plastic material. Packaged bait is easily placed in burrows, crevices, small holes, spaces in walls, and other tight places. Mice commonly gnaw into these packages to feed on the bait. Pellets are sometimes "hoarded" by mice and carried off to another location. This may pose a danger when mice carry the poisoned bait to areas accessible by nontarget animals. However, pellets are preferable over loose-meal bait as there is no settling of different-sized bait particles during shipping and uneven mixing of poison in the bait.

Paraffin or Wax Blocks:
Wax blocks containing poisoned grain are useful where moisture may cause grain spoilage. However, acceptance may be a problem because mice generally prefer loose or pelleted grain bait over paraffin blocks.

Water or High-Moisture Baits:
In areas lacking available water, these baits readily attract mice that opportunistically drink water when available. Sodium salts of anticoagulants are mixed with water to produce liquid bait. However, mice can detect anticoagulants easier in water baits than in food baits. For this reason, a 5-percent sugar mixture is used to mask anticoagulants. These baits are very effective for grain storage structures, warehouses, and other water-deficient areas. When water baits are used during freezing weather, the addition of approximately 10 percent glycerin will prevent freezing. Care should be exercised when locating water baits to avoid poisoning non-target animals.

Bait Stations

Bait stations increase the effectiveness of controlling mice and enhance safety. A bait station or box allows a continuous supply of bait for mice without compromising the safety of non-target animals and children. A continual, available supply of bait is especially important when using anticoagulants. A good rule of thumb for effective control with bait stations is to double the amount of rodenticide used if the initial bait amount is completely consumed.

Bait stations improve the effectiveness of a control program by providing an attractive feeding site that also offers a high sense of security for unsuspecting mice. Other advantages of bait stations include enhanced safety for children and non-target animals, and protection of the bait from moisture and dust. A simple bait station can be established by leaning a wood board against a wall or baseboard with adequate fresh bait underneath.

Other advantages of bait stations include protection of the bait from moisture and dust and providing an attractive place for feeding mice. Mice prefer feeding inside boxes or sheltered areas because this provides them with a strong sense of security. Bait stations also permit locating poisons in otherwise difficult areas due to weather or hazards to non-target animals. They also help prevent accidental spilling of bait and allow easy inspection to assess bait consumption.

Bait stations for both solid or liquid baits can be purchased or constructed from scrap materials. Purchased bait stations from commercial manufacturers are available in plastic, wood, metal, or cardboard. Research has shown that mice prefer to feed from cardboard stations. Agricultural supply stores usually have different sizes available for both rats and mice. When building homemade stations, use sturdy, hard-to-damage materials that cannot be easily knocked or moved out of place. Design the station so bait is accessible only to rodents, especially if children or non-target animals are present. Try to make the station tamper-proof by adding locks, concealed latches, or seals. For additional safety, label the boxes with poison warnings.

Well-designed bait stations allow several mice to feed at the same time. They should also be large enough to accommodate an adequate amount of bait. A simple station could be a section of pipe 2 to 3 inches in diameter and at least 18 inches in length, placed against a wall. A wood board, 2 inches thick by 8 inches wide and 18 inches or longer, leaning against a wall or baseboard also works well as a feeding station. However, make sure the space beneath the board is small enough that children and pets can't reach the bait.

More elaborate bait stations can be made to accommodate both liquid and solid food baits within a hinged and clasped wood box. On closed boxes, drill small entrance and exit holes at least 1 inch in diameter at both ends. The holes should be at opposite ends of the box so mice can easily see an escape route.

Newly located bait stations should be filled with adequate fresh bait and checked daily. Avoid using spoiled or stale baits, and add fresh bait as needed. In a short time, mouse numbers and feeding levels will decline, thereby requiring only a check every couple of weeks. Discard moldy, musty, soiled, or insect-infested bait and refill with fresh bait when required. When using bait stations, always follow label directions for prepared baits and dispose of uneaten bait properly.

Bait stations must be placed in proper locations for maximum effectiveness. This is probably equally important as selecting the proper bait. Because mice have small areas of activity and do not have specific food preferences, bait stations must be located in areas of high mouse activity for successful control.

For best success, place bait stations between nesting or shelter areas and their food source along frequently used pathways. These areas are normally against walls or along buildings. When mice feed on boxed or sacked feed on wooden pallets, place bait stations between gaps of the pallets or on top of the food cartons. Be careful when using baits that could contaminate food on the pallets. In this situation, alternate control methods such as traps or glue boards might be better than toxic baits.

On farms and ranches, placement of bait stations depends on the presence of livestock and building design. Where livestock can disturb bait stations, consider placing them on wall ledges or tops of pen dividers if the building design permits. Visible rodent tracks and droppings signify mice activity centers and thereby provide ideas for bait station placement. Never locate bait stations where pets or other animals can disturb them. Spilled bait is a hazard, especially to small animals.

Strategic placement of bait stations outside non-rodent-proof buildings can hold mice populations at low levels by controlling mice that move in from surrounding areas. Stations can be placed around building foundations, along perimeters of buildings, and inside structures. Keep stations stocked with fresh anticoagulant bait for maximum effectiveness.

Tracking Powder

Tracking powder is effective in situations where mouse food abounds and bait acceptance is poor. This form of lethal control has been successfully used for many years.

Tracking powders contain poisons that are picked up on feet or fur and ingested during grooming. Poison shyness does not develop because mice rarely associate getting sick with grooming activities. The concentration of poison in tracking powders is much higher compared to bait using the same ingredient to compensate for the small amount ingested during grooming. For this reason, tracking powders are more hazardous to use than food baits. They are generally used only by professionally trained control specialists. Single-dose toxicants and anticoagulants are commercially available in tracking powders, with some labeled as restricted-use pesticides.

Tracking powders are generally placed along runways, in walls, on bait-station floors, or anywhere mice travel using sifters, shakers, or dusters. Dampness can cause the powder to cake, resulting in decreased effectiveness. Because tracking powders are potentially hazardous, they should be used only where food cannot be contaminated or where non-target animals, pets and livestock cannot be affected. If possible, remove tracking powder after a control program is finished.

When used in conjunction with baiting, tracking powders can provide very effective control on mouse populations. However, because of the potential hazards to children and pets, they are not recommended for residential use.

Fumigants

Fumigants are used to control mice in structures and other enclosed areas where large populations exist. However, this type of control is only practical and cost-effective in situations where severe damage problems persist. Fumigants are very hazardous and too dangerous for use by untrained applicators and therefore are not recommended for controlling mice.

Traps

Trapping is the most labor-intensive method of controlling mice but effective for small areas where only a few mice exist. Trapping is also recommended where poisons may cause danger to children, pets, or livestock. Trapping is ideal for areas such as garages, homes, and other small structures. The advan-

Trapping is effective for small areas such as garages and homes where only a few mice exist and where poisons may cause danger to children, pets, or livestock. Placing traps so the trigger mechanism is located in natural travel courses and enlarging the trigger area with a piece of cardboard improves trapping effectiveness.

Improper trap placement is the most common cause of poor trapping success. Single traps should be placed against walls with the trigger mechanism closest to the wall (right). Traps placed too far from the wall (center) or those with trigger mechanisms oriented away from the wall (left) are generally ineffective.

Two traps set next to each other, with trigger mechanisms closest to the interior wall, improve trapping efficiency by increasing the trigger area.

tages of trapping are: (1) non-use of hazardous rodenticides, (2) readily visible evaluation of control success, and (3) rapid disposal of carcasses, which eliminates odor problems and potential human health risks.

Compared to other control methods, trapping is relatively inexpensive. Simple, inexpensive snap traps are commercially available at most grocery, hardware, and farm-supply stores.

A variety of baits work well with snap traps including nutmeats, chocolate candy, gumdrops, bacon, dried fruit, marshmallows, or peanut butter. Baits should be tied to the trigger using wire, thread, or string. Always use fresh bait because stale foods become ineffective. Non-food baits such as cotton balls and jute fiber will also work; mice always search for nesting materials.

This parallel trap arrangement, using two traps against an interior wall, is another trap placement design that improves trapping efficiency. For maximum effectiveness, place traps so that trigger mechanisms face outward (right) rather than inward (left).

For maximum effectiveness, traps should be placed in areas of obvious mouse activity. Good places to set traps are usually along walls, behind larger objects such as furniture or junk piles, and in dark places. Situate the traps so mice will pass directly over the trigger as they follow their natural course of travel. Setting a sensitive trigger and / or enlarging the trigger will improve trapping effectiveness. To enlarge the trigger, place a square of cardboard, metal, or screen wire just inside the wire deadfall and over the trigger. Bait is not needed for enlarged triggers.

Proper trap placement in areas of mouse activity is also essential for improving effectiveness. For example, traps placed along walls should be positioned with the trigger closest to the wall. When using double traps (two traps side-by-side), place them next to one another with the triggers against the wall, or parallel to the wall with triggers facing outside on either end. Improper placement is the most common reason for failed trapping.

To avoid mice becoming trap shy, place enough traps to control the population quickly and thoroughly. Because mice stay close to nesting areas and food supplies, space traps about 6 to 8 feet apart in activity centers. To increase efficiency, leave the traps baited but unset for a few days before beginning trapping. This will give mice a false sense of security and reduce escapes and trap-shyness. Every couple of days move the traps 24 inches from the previous location.

There are a variety of other types of traps available including automatic multiple-capture traps under the registered trademark names of Ketch-All

Mouse Trap and Victor Tin Cat. These traps are generally live-traps that require regular checking and releasing of mice away from a house or building before they die of exposure or starvation. There are also box-type traps designed to capture one mouse per setting. These are primarily used for research purposes.

All traps should be kept clean and in good working condition. Periodically wash them using a detergent and stiff brush when dirty. Human and dead mouse odors on traps do not seem to reduce trapping success with mice.

Glue Boards

Glue boards, another trapping method, catch and hold mice traveling across the sticky board. They are also placed along established travel lanes or pathways. Glue boards can be purchased ready-to-use, or glue may be purchased separately and used on homemade boards. Temperature extremes and dust will reduce the effectiveness of glue boards. Mice caught on glue boards are generally drowned or killed by a sharp blow to the base of the skull. Glue boards should not be used in the presence of children, pets, or other non-target animals.

Glue boards are another trapping method that catch and hold mice traveling along established pathways. They are commercially available or can be constructed from home materials and purchased glue.

Domestic Predators

Contrary to popular belief, dogs and cats cannot totally eliminate mouse populations. In fact, the presence of pets more than likely helps mice prosper by providing a readily available food source, either from stored pet food or pet dishes while a dog or cat is asleep or away.

Around most buildings or structures, especially in urban areas, mice live in close association with cats and dogs. There are many protective areas where mice hide and nest out of the reach of domestic predators.

In rural areas, a sufficient number of cats may be able to prevent mouse reinvasion following control practices. However, they probably do not eliminate mouse populations entirely.

Household pets such as dogs and cats do little to control mouse populations. In fact, stored pet food and feeding dishes attract mice by providing an easily available food source.

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