RODENTS

James E. Miller
Program Leader, Fish and Wildlife
USDA — Extension Service
Natural Resources and Rural
Development Unit
Washington, DC 20250

Greg K. Yarrow
Extension Wildlife Specialist
Department of Aquaculture, Fisheries,
and Wildlife
Clemson University
Clemson, South Carolina 29634-0362

BEAVERS

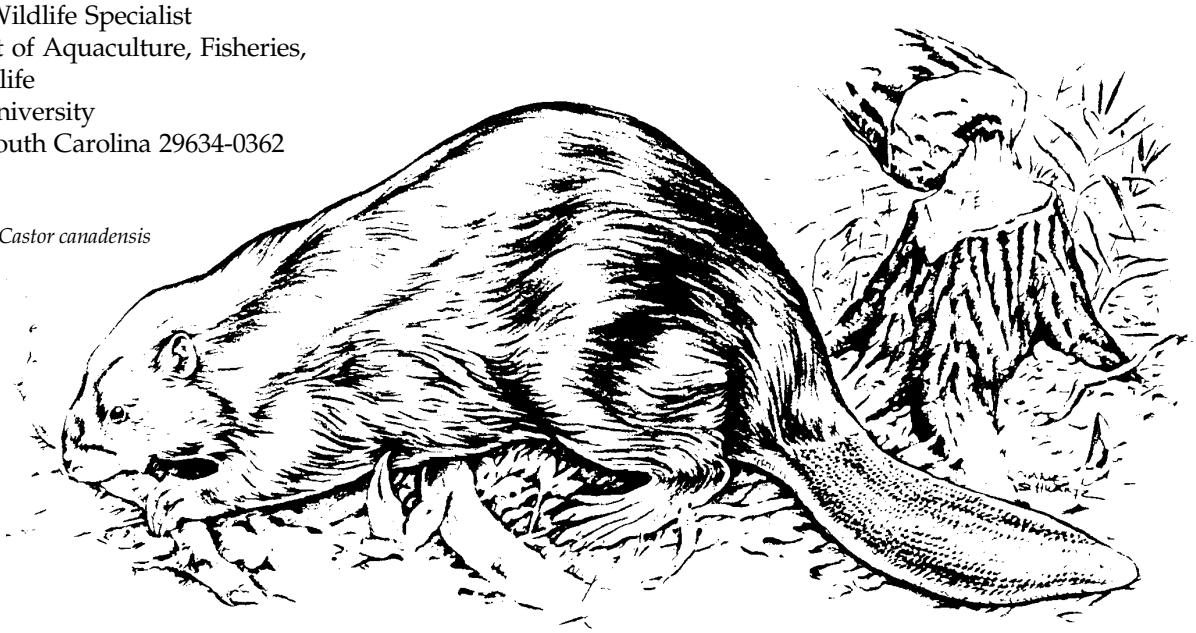


Fig. 1. Beaver, *Castor canadensis*

Damage Prevention and Control Methods

Exclusion

Fence small critical areas such as culverts, drains, or other structures.

Install barriers around important trees in urban settings.

Cultural Methods and Habitat Modification

Eliminate foods, trees, and woody vegetation where feasible.

Continually destroy dams and materials used to build dams.

Install a Clemson beaver pond leveler, three-log drain, or other structural device to maintain a lower pond level and avoid further pond expansion.

Frightening

Shooting of individuals or dynamiting or other continued destruction of lodges, bank dens, and dams, where legal, will occasionally move young colonies out of an area.

Repellents

None are registered; however, there is some evidence that repellents may be useful.

Toxicants

None are registered.

Trapping

No. 330 Conibear® traps.

Leghold traps No. 3 or larger (including coil-spring types with equivalent jaw spread and impact).

Basket/suitcase type traps are primarily used for live trapping.

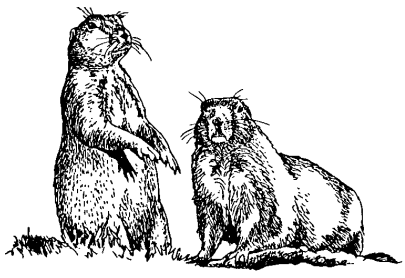
Snares can be useful, particularly in dive sets and slides where legal.

Shooting

Rarely effective (where legal) for complete control efforts and can be dangerous to humans.

Other Methods

Other methods rarely solve a beaver damage problem and may increase risks to humans and nontarget species.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

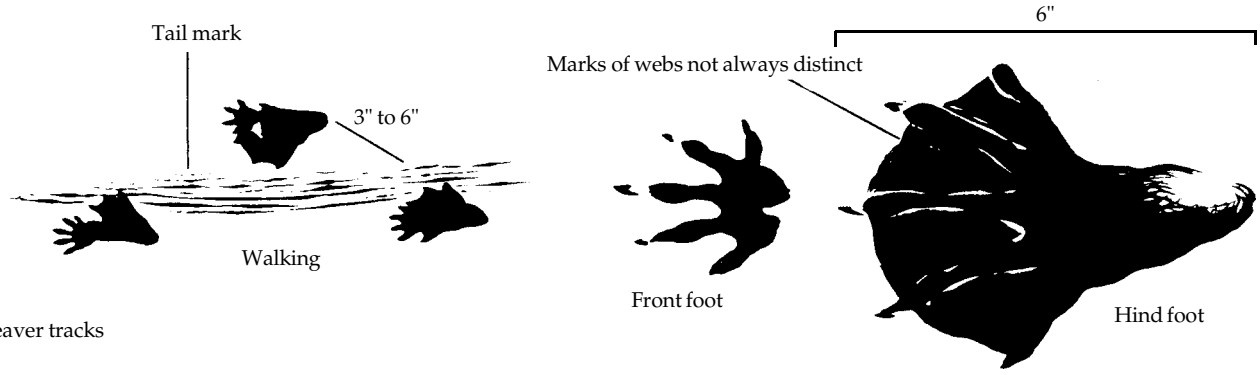


Fig. 2. Beaver tracks

Identification

The beaver (*Castor canadensis*, Fig. 1) is the largest North American rodent. Most adults weigh from 35 to 50 pounds (15.8 to 22.5 kg), with some occasionally reaching 70 to 85 pounds (31.5 to 38.3 kg). Individuals have been known to reach over 100 pounds (45 kg). The beaver is a stocky rodent adapted for aquatic environments. Many of the beaver's features enable it to remain submerged for long periods of time. It has a valvular nose and ears, and lips that close behind the four large incisor teeth. Each of the four feet have five digits, with the hind feet webbed between digits and a split second claw on each hind foot. The front feet are small in comparison to the hind feet (Fig. 2). The underfur is dense and generally gray in color, whereas the guard hair is long, coarse and ranging in color from yellowish brown to black, with reddish brown the most common coloration. The prominent tail is flattened dorso-ventrally, scaled, and almost hairless. It is used as a prop while the beaver is sitting upright (Fig. 3) and for a rudder when swimming. Beavers also use their tail to warn others of danger by abruptly slapping the surface of the water.The beaver's large front (incisor) teeth, bright orange on the front, grow continuously throughout its life. These incisors are beveled so that they are continuously sharpened as the beaver gnaws and chews while feeding, girdling, and cutting trees. The only way to externally distinguish the sex of a beaver, unless the female is lactating, is to feel for the presence of a baculum (a bone in the penis) in males and its absence in females.

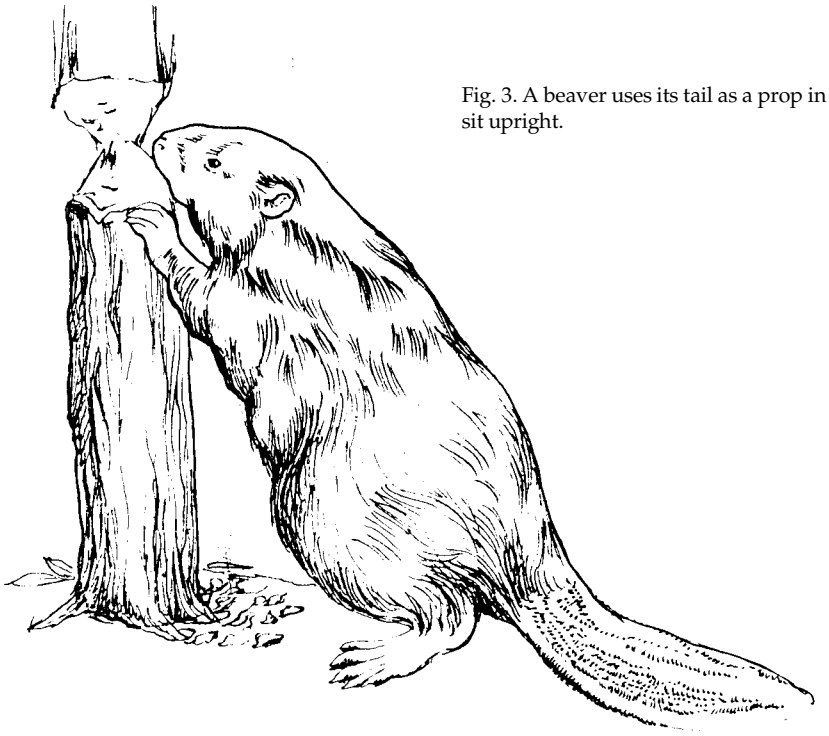
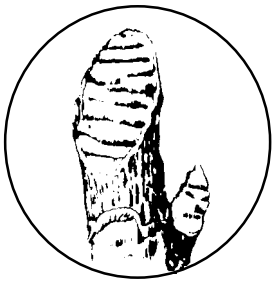


Fig. 3. A beaver uses its tail as a prop in order to sit upright.



Details of beaver cuttings.

Fig. 4. Range of the beaver in North America.

Range

Beavers are found throughout North America, except for the arctic tundra, most of peninsular Florida, and the southwestern desert areas (Fig. 4). The species may be locally abundant wherever aquatic habitats are found.

Habitat

Beaver habitat is almost anywhere there is a year-round source of water, such as streams, lakes, farm ponds, swamps, wetland areas, roadside ditches, drainage ditches, canals, mine pits, oxbows, railroad rights-of-way, drains from sewage disposal ponds, and below natural springs or artesian wells. Beavers build dams to modify the environment more to their liking. Dam building is often stimulated by running water. The length or height of a dam generally depends upon what is necessary to slow the flow of water and create a pond. In areas of flat topography, the dam may not be over 36 inches (0.9 m) high but as much as 1/4 miles (0.4 km) long. In hilly or mountainous country, the dam may be 10 feet (3 m) high and only 50 feet (15 m) long. Beavers are adaptable and will use whatever materials are available to construct dams — fencing materials, bridge planking, crossties, rocks, wire, and other metal, wood, and fiber materials. Therefore, about the only available aquatic habitat beavers avoid are those systems lacking acceptable foods, lodge or denning sites, or a suitable dam site. Some of the surrounding timber is cut down or girdled by beavers to form dams. Subsequent flooding of growing timber causes it to die, and aquatic vegetation soon begins growing. Other pioneer species (for example, willow, sweetgum, and buttonbush) soon grow around the edges of the flooded area, adding to the available food supply. The beaver thus helps create its own habitat.

Food Habits

Beavers prefer certain trees and woody species, such as aspen, cottonwood, willow, sweetgum, blackgum, black cherry, tulip poplar, and pine, depending on availability. However, they can and will eat the leaves, twigs, and bark of most species of woody plants that grow near the water, as well as a wide variety of herbaceous and aquatic plants. Beavers often travel 100 yards (90 m) or more from a pond or stream to get to corn fields, soybean fields, and other growing crops, where they cut the plants off at ground level and drag them back to the water. They eat parts of these plants and often use the remainder as construction material in the dam.

General Biology, Reproduction, and Behavior

Beavers are active for approximately 12 hours each night except on the coldest of winter nights. The phrase "busy as a beaver" is appropriate. It is not uncommon, however, to see beavers during daylight hours, particularly in larger reservoirs.

Beavers are generally monogamous; copulation may take place either in the water or in the lodge or bank den.

After a gestation period of about 128 days, the female beaver generally gives birth to 3 or 4 kittens between March and June, and nurses them for 6 weeks to 3 months. The kittens are born fully furred with their eyes partially opened and incisors erupted through the gums. They generally become sexually mature by the age of 1 1/2 years.

Beaver communicate by vocalizations, posture, tail slapping, and scent posts or mud mounds placed around the bank and dam. The beaver's castor glands secrete a substance that is deposited on mud mounds to mark territorial boundaries. These scent posts are found more frequently at certain seasons, but are found yearround in active ponds.

Fig. 5. Cross section of a beaver lodge.

Beavers have a relatively long life span, with individuals known to have lived to 21 years. Most, however, do not live beyond 10 years. The beaver is unparalleled at dam building and can build dams on fast-moving streams as well as slow-moving ones. They also build lodges and bank dens, depending on the available habitat. All lodges and bank dens have at least two entrances and may have four or more. The lodge or bank den is used primarily for raising young, sleeping, and food storage during severe weather (Fig. 5).

The size and species of trees the beaver cuts is highly variable — from a 1-inch (2.5-cm) diameter at breast height (DBH) softwood to a 6-foot (1.8-m) DBH hardwood. In some areas beavers usually cut down trees up to about 10 inches (25 cm) DBH and merely girdle or partially cut larger ones, although they often cut down much larger trees. Some beavers seem to like to girdle large pines and sweetgums. They like the gum or storax that seeps out of the girdled area of sweetgum and other species.

An important factor about beavers is their territoriality. A colony generally consists of four to eight related beavers, who resist additions or outsiders to the colony or the pond. Young beavers are commonly displaced from the colony shortly after they become sexually mature, at about 2 years old. They often move to another area to begin a new pond and colony. However, some become solitary hermits inhabiting old abandoned ponds or farm ponds if available.

Beavers have only a few natural predators aside from humans, including coyotes, bobcats, river otters, and mink, who prey on young kittens. In other areas, bears, mountain lions, wolves, and wolverines may prey on beavers. Beavers are hosts for several ectoparasites and internal parasites including nematodes, trematodes, and coccidians. *Giardia lamblia* is a pathogenic intestinal parasite transmitted by beavers, which has caused human health problems in water supply systems. The Centers for Disease Control have recorded at least 41 outbreaks of waterborne Giardiasis, affecting more than 15,000 people. For more information about Giardiasis, see von Oettingen (1982).

Fig. 6. Pine plantation in Arkansas killed in flooding caused by beavers.

Damage and Damage Identification

The habitat modification by beavers, caused primarily by dam building, is often beneficial to fish, furbearers, reptiles, amphibians, waterfowl, and shorebirds. However, when this modification comes in conflict with human objectives, the impact of damage may far outweigh the benefits.

Most of the damage caused by beavers is a result of dam building, bank burrowing, tree cutting, or flooding. Some southeastern states where beaver damage is extensive have estimated the cost at $3 million to $5 million dollars annually for timber loss; crop losses; roads, dwellings, and flooded property; and other damage. In some states, tracts of bottomland hardwood timber up to several thousand acres (ha) in size may be lost because of beaver. Some unusual cases observed include state highways flooded because of beaver ponds, reservoir dams destroyed by bank den burrows collapsing, and train derailments caused by continued flooding and burrowing. Housing developments have been threatened by beaver dam flooding, and thousands of acres (ha) of cropland and young pine plantations have been flooded by beaver dams (Fig. 6). Road ditches, drain pipes, and culverts have been stopped up so badly that they had to be dynamited out and replaced. Some bridges have been destroyed because of beaver dam-building activity. In addition, beavers threaten human health by contaminating water supplies with *Giardia.*

Identifying beaver damage generally is not difficult. Signs include dams; dammed-up culverts, bridges, or drain pipes resulting in flooded lands, timber, roads, and crops; cut-down or girdled trees and crops; lodges and burrows in ponds, reservoir levees, and dams. In large watersheds, it may be difficult to locate bank dens. However, the limbs, cuttings, and debris around such areas as well as dams along tributaries usually help pinpoint the area.

Legal Status

The legal status of beavers varies from state to state. In some states the beaver is protected except during furbearer seasons; in others it is classified as a pest and may be taken year-round when causing damage. Because of its fur value, dam building, and resulting water conservation, it is generally not considered a pest until economic losses become extensive. Fur prices for beaver in some states, particularly in the Southeast, make it hardly worth the skinning and stretching. In some northern states, trapping is prohibited near lodges or bank dens to protect and perpetuate beaver colonies. Fur prices for beaver pelts are usually much higher in these areas.

Damage Prevention and Control Methods

Exclusion

It is almost impossible as well as cost-prohibitive to exclude beavers from ponds, lakes, or impoundments. If the primary reason for fencing is to exclude beavers, fencing of large areas is not practical. Fencing of culverts, drain pipes, or other structures can sometimes prevent damage, but fencing can also promote damage, since it provides beavers with construction material for dams. Protect valuable trees adjacent to waterways by encircling them with hardware cloth, woven wire, or other metal barriers. Construction of concrete spillways or other permanent structures may reduce the impact of beavers.

Cultural Methods

Because beavers usually alter or modify their aquatic habitat so extensively over a period of time, most practices generally thought of as cultural have little impact on beavers. Where feasible, eliminate food, trees, and woody vegetation that is adjacent to beaver habitat. Continual destruction of dams and removal of dam construction materials daily will (depending on availability of construction materials) sometimes cause a colony or individual beavers to move to another site. They might, however, be even more troublesome at the new location.

The use of a three-log drain or a structural device such as wire mesh culverts (Roblee 1983) or T-culvert guards (Roblee 1987) will occasionally cause beavers to move to other areas. They all prevent beavers from controlling water levels. However, once beavers have become abundant in a watershed or in a large contiguous area, periodic reinvasions of suitable habitat can be expected to occur. Three-log drains have had varying degrees of success in controlling water levels in beaver impoundments, especially if the beaver can detect the sound of falling water or current flow. All of these devices will stimulate the beavers to quickly plug the source of water drainage.

A new device for controlling beaver impoundments and keeping blocked culverts open is the Clemson beaver pond leveler. It has proven effective in allowing continual water flow in previously blocked culverts/drains and facilitating the manipulation of water levels in beaver ponds for moist-soil management for waterfowl (Wood and Woodward 1992) and other environmental or aesthetic purposes. The device (Fig. 7) consists of a perforated PVC pipe that is encased in heavy-gauge hog wire. This part is placed upstream of the dam or blocked culvert, in the main run or deepest part of the stream. It is connected to nonperforated sections of PVC pipe which are run through the dam or culvert to a water control structure downstream. It is effective because the beavers cannot detect the sound of falling or flowing water as the pond or culvert drains; therefore, they do not try to plug the pipe. The Clemson beaver pond leveler works best in relatively flat terrain where large volumes of water from watersheds in steep terrain are not a problem.

Repellents

There are no chemical repellents registered for beavers. Past research efforts have tried to determine the effectiveness of potential repellent materials; however, none were found to be effective, environmentally safe, or practical. One study in Georgia (Hicks 1978) indicated that a deer repellent had some potential benefit. Other studies have used a combination of dam blowing and repellent soaked (Thiram 80 and/or paradichlorobenzene) rags to discourage beavers with varying degrees of success (Dyer and Rowell 1985).

Additional research is needed on repellents for beaver damage prevention.

Toxicants

None are registered. Research efforts have been conducted, however, to find effective, environmentally safe and practical toxicants. Currently there are none that meet these criteria.

Fumigants

None are registered.

Trapping

The use of traps in most situations where beavers are causing damage is the most effective, practical, and environmentally safe method of control. The effectiveness of any type of trap for beaver control is dependent on the trapper's knowledge of beaver habits, food preferences, ability to read beaver signs, use of the proper trap, and trap placement. A good trapper with a dozen traps can generally trap all the beavers in a given pond (behind one dam) in a week of trap nights. Obviously in a large watershed with several colonies, more trapping effort will be required. Most anyone with trapping experience and some outdoor "savvy" can become an effective beaver trapper in a short time. In an area where beavers are common and have not been exposed to trapping, anyone experienced in trapping can expect good success. Additional expertise and improved techniques will be gained through experience.

A variety of trapping methods and types of traps are effective for beavers, depending on the situation. Fish and wildlife agency regulations vary from

Table 1. List of materials for the Clemson Beaver Pond Leveler.

Quantity	Item
1	10' section, 10" diameter PVC pipe (Schedule 40)
1	PVC cap for 10" diameter PVC pipe (Schedule 40)
1	10" x 8" PVC pipe reducer coupling (Schedule 40)
4	86" sections, 3/4" diameter plastic roll pipe (water pipe), 160 psi grade
4	3/4" metal couplings for roll pipe
16	1/4" x 2" galvanized eyebolts
16	1/4" galvanized nuts
16	1/4" galvanized washers
16	16" sections, 8 gauge galvanized wire (medium hardness)
2	96" sections, 2" x 4" 1/2 gauge galvanized welded wire
2 lbs	Crab trap clamps (fasteners)

The above materials are required to assemble the intake device. The carrying pipe (flow pipe) may consist of 20 to 40 feet of 8-inch diameter PVC, Schedule 40 with coupling sleeves and elbows appropriate to the desired configuration.

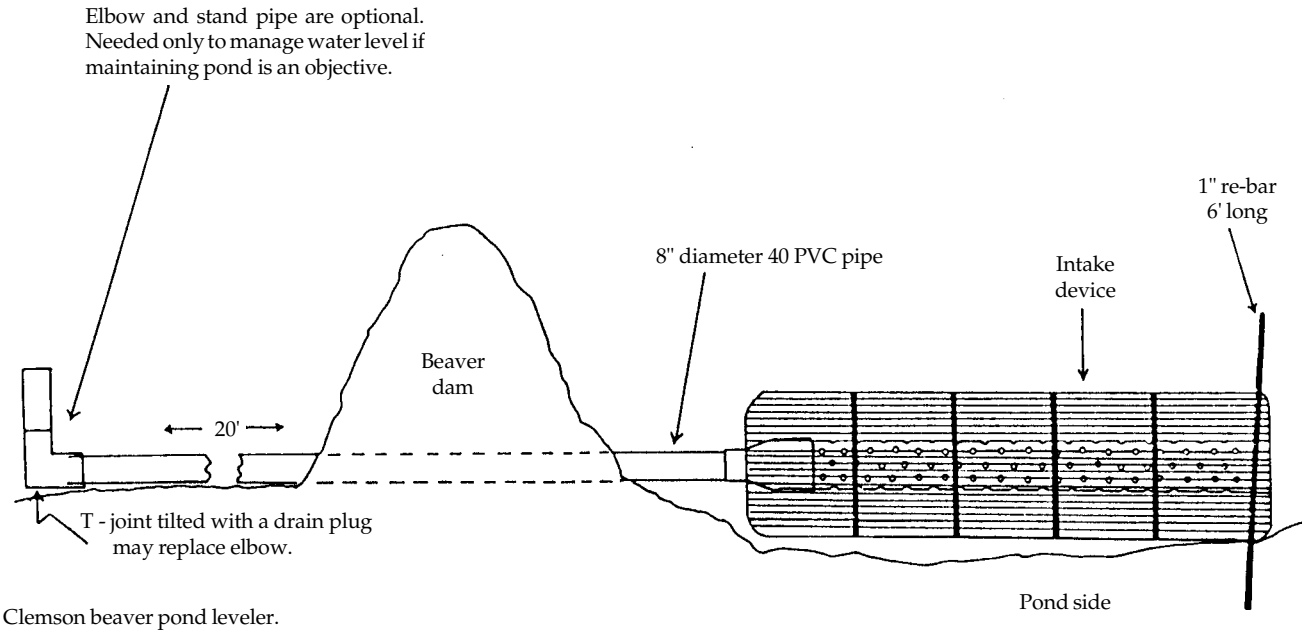


Fig. 7. Clemson beaver pond leveler.

state to state. Some types of traps and trapping methods, although effective and legal in some states, may be prohibited by law in other states. Individual state regulations must be reviewed annually before beginning a trapping program

In some states where beavers have become serious economic pests, special regulations and exemptions have been passed to allow for increased control efforts. For example, some states allow trapping and snaring of beavers and other control measures throughout the year. Others, however, prohibit trapping except during established fur trapping seasons. Some states allow exemptions for removal of beavers only on lands owned or controlled by persons who are suffering losses. In some states a special permit is required from the state fish and wildlife agency.

Of the variety of traps commonly allowed for use in beaver control, the Conibear® type, No. 330, is one of the most effective (Fig. 8). Not all trappers will agree that this type of trap is the most effective; however, it is the type most commonly used by professional trappers and others who are principally trapping beavers. This trap kills beavers almost instantly. When properly set, the trap also prevents any escape by a beaver, regardless of its size. Designed primarily for water use, it is equally effective in deep and shallow water. Only one trap per site is generally necessary, thus reducing the need for extra traps. The trap exerts tremendous pressure and impact when tripped. Appropriate care must be exercised when setting and placing

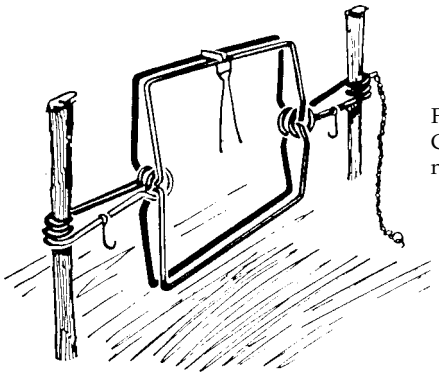


Fig. 8. Basic method of setting and staking a Conibear® 330 trap. Additional stakes are normally used (see Fig. 9).

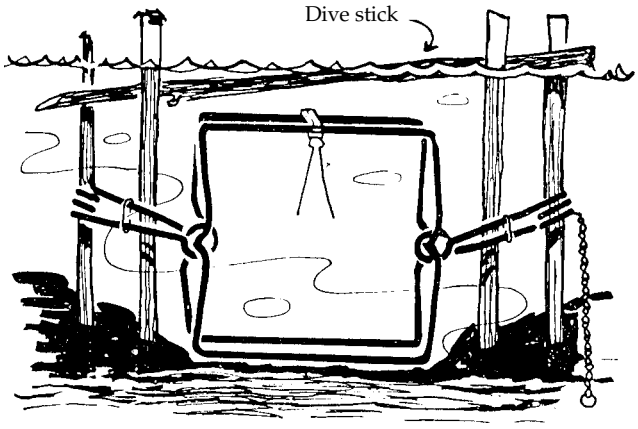


Fig. 9. Conibear trap in dive set.

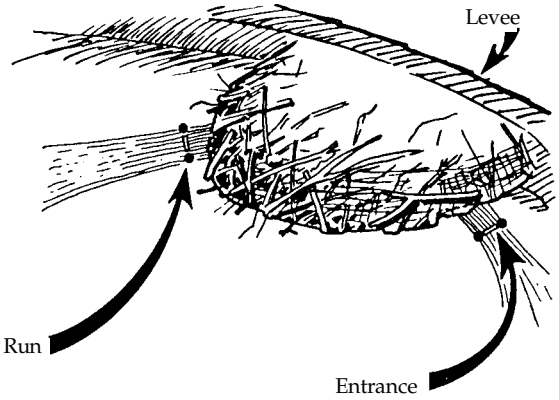


Fig. 10. Runs or underwater entrances to lodges are good places to set beaver traps.

the trap. Care should also be taken when using the Conibear® type traps in urban and rural areas where pets (especially dogs) roam free. Use trap sets where the trap is placed completely underwater.

Some additional equipment will be useful: an axe, hatchet, or large cutting tool; hip boots or waders; wire; and wire cutters. With the Conibear®-type trap, some individuals use a device or tool called "setting tongs." Others use a piece of 3/8- or 1/2-inch (9- or 13-mm) nylon rope. Most individuals who are experienced with these traps use only their hands. Regardless of the techniques used to set the trap, care should be exercised.

Earlier models of the Conibear® type of trap came with round, heavy steel coils which were dangerous to handle unless properly used in setting the trap. They are not necessary to safely set the trap. However, the two safety hooks, one on each spring, must be carefully handled as each spring is depressed, as well as during trap placement. On newer models an additional safety catch (not attached to the springs) is included for extra precaution against inadvertent spring release. The last step before leaving a set trap is to lift the safety hook attached to each spring and slide the safety hook back from the trap toward the spring eye, making sure to keep hands and feet safely away from the center of the trap. If the extra (unattached) safety catch is used, it should be removed before the safety hooks that are attached to the springs to keep it from getting in the way of the movement of the safety hooks.

Conibear®-type traps are best set while on solid ground with dry hands. Once the springs are depressed and the safety hooks in place, the trap or traps can be carried into the water for proper placement. Stakes are needed to anchor the trap down. In most beaver ponds and around beaver dams, plenty of suitable stakes can be found. At least two strong stakes, preferably straight and without forks or snags, should be chosen to place through each spring eye (Fig. 8). Additional stakes may be useful to put between the spring arms and help hold the trap in place. Do not place stakes on the outside of spring arms. Aside from serving to hold the trap in place, these stakes also help to guide the beaver into the trap. Where needed, they are also useful in holding a dive stick at or just beneath the water surface (Fig. 9). If necessary, the chain and circle attached to one spring eye can be attached to another stake. In deep water sets, a chain with an attached wire should be tied to something at or above the surface so the trapper can retrieve the trap. Otherwise the trap may be lost.

Trap Sets. There are many sets that can be made with a Conibear®-type trap (for example, dam sets, slide sets, lodge sets, bank den sets, "run"/trail sets, under log/dive sets, pole sets, under ice sets, deep water sets, drain

pipe sets), depending on the trapper's capability and ingenuity. In many beaver ponds, however, most beavers can be trapped using dam sets, lodge or bank den sets, sets in "runs"/trails, dive sets or sets in slides entering the water from places where beavers are feeding. Beavers swim both at the surface or along the bottom of ponds, depending on the habitat and water depth. Beavers also establish runs or trails which they habitually use in traveling from lodge or den to the dam or to feeding areas, much like cow trails in a pasture.

Place traps directly across these runs, staked to the bottom (Fig. 10).

Use a good stake or "walking staff' when wading in a beaver pond to locate deep holes, runs, or trails. This will prevent stepping off over waders or hip boots in winter, and will help ward off cottonmouth snakes in the summer. The staff can also help locate good dive holes under logs as you walk out runs or trails. In older beaver ponds, particularly in bottomland swamps, it is not uncommon to find runs and lodge or bank den entrances where the run or hole is 2 to 3 feet (0.6 to 0.9 m) below the rest of the impoundment bottom.

To stimulate nighttime beaver movement, tear a hole in a beaver dam and get the water moving out of a pond. Beavers quickly respond to the sound of running water as well as to the current flow. Timing is also important if you plan to make dam sets. Open a hole in the dam about 18 inches to 2 feet (46 to 60 cm) wide and 2 to 3 feet (60 to 90 cm) below the water level on the upper side of the dam in the morning. This will usually move a substantial amount of water out of the pond before evening (Fig. 11). Set traps in front of the dam opening late that same evening. Two problems can arise if you set a trap in the morning as soon as a hole is made: (1) by late evening, when the beavers become active, the trap may be out of the water and ineffective; or (2) a stick, branch, or other debris in the moving water may trip the trap, again rendering it ineffective.

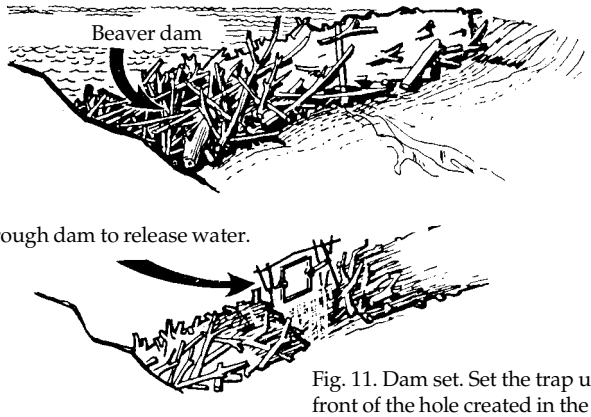


Fig. 11. Dam set. Set the trap underwater in front of the hole created in the dam. When the beaver returns to patch the hole, it will be caught in the trap.

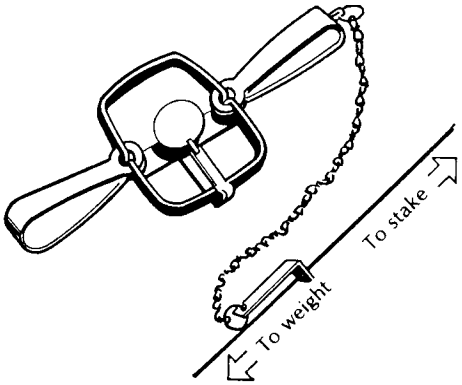


Fig. 12. Leghold trap (No. 3 or No. 4, double spring) attached to wire for drowning set.

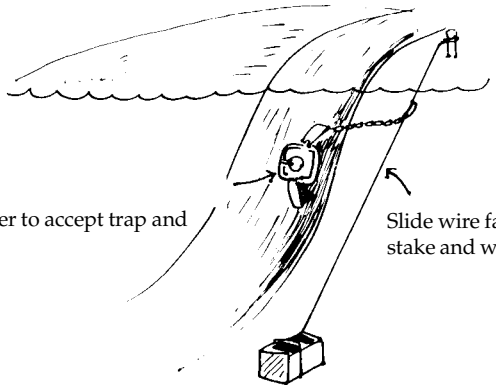


Fig. 13. Leghold trap in slide set.

The best dam sets are made about 12 to 18 inches (30.8 to 45.7 cm) in front of the dam itself. Using stakes or debris on either side of the trap springs, create a funnel to make the beaver go into the jaws of the trap. Always set the trigger on the Conibear®-type trap in the first notch to prevent debris from tripping it before the beaver swims into the trap. The two heavy-gauge wire trippers can be bent outward and the trigger can be set away from the middle if necessary, to keep debris from tripping the trap. This can also keep small beaver or possibly fish or turtles from springing the trap.

Double-spring leghold traps have been used for hundreds of years and are still very effective when properly used by skilled trappers. Use at least No. 3 double (long) spring or coil spring type leghold traps or traps of equivalent size jaw spread and strength. Use a drowning set attachment with any leghold trap (Fig. 12). As the traps are tripped, the beaver will head for the water. A weight is used to hold the trapped beaver underwater so that it ultimately drowns. Some trappers stake the wire in deep water to accomplish drowning. If leghold traps are not used in a manner to accomplish drowning, there is a good likelihood that legs or toes will be twisted off or pulled loose, leaving an escaped, trap-wise beaver.

Placement is even more critical with leghold traps than with the Conibear®-type. Place leghold traps just at the water's edge, slightly underwater, with the pan, jaws, and springs covered lightly with leaves or debris or pressed gently into the pond bottom in soft mud. Make sure there is a cavity under the pan so that when the beaver's foot hits the pan, it will trigger the trap and allow the jaws to snap closed. Place traps off-center of the trail or run to prevent "belly pinching" or missing the foot or leg. With some experience, beaver trappers learn to make sets that catch beavers by a hind leg rather than a front leg. The front leg is much smaller and easier to twist off or pull out.

Sometimes it's wise, when using leghold traps, to make two sets in a slide, run, dam, or feeding place to increase trapping success and remove beavers more quickly. In some situations, a combination of trapping methods can shorten trapping time and increase success.

Trappers have come up with unique methods of making drown sets. One of the simplest and most practical is a slide wire with a heavy weight attached to one end, or with an end staked to the bottom in 3 or more feet (>0.9 m) of water. The other end of the wire is threaded through a hole in one end of a small piece of angle iron. The trap chain is attached to a hole in the other end of the angle. The end of the wire is then attached to a tree or stake driven into the bank (Fig. 13). When the beaver gets a foot or leg in the trap, it immediately dives back into the water. As the angle slides down the wire, it prevents the beaver from reaching the surface. The angle iron piece will not slide back up the wire and most often bends the wire as the beaver struggles, thus preventing the beaver from coming up for air. Trappers should be prepared to quickly and humanely dispatch a beaver that is caught in a trap and has not drowned.

The leghold trap set in lodges or bank dens is also effective, especially for trapping young beavers. Place the set on the edge of the hole where the beaver first turns upward to enter the lodge or den, or place it near the bottom of the dive hole. Keep the jaws and pan off of the bottom by pulling the springs backward so that a swimming foot will trip the pan. Stake the set close to the bottom or wire the trap to a log or root on the bottom, to avoid the need for drowning weights, wires, and angle iron pieces. Generally, more time and expertise is necessary to make effective sets with leghold traps and snares than is required with the Conibear®-type trap.

Use scent or freshly cut cottonwood, aspen, willow, or sweetgum limbs to entice beaver to leghold trap sets. Bait or scent is especially useful around scent mounds and up slides along the banks or dams. Most trappers who use Conibear®-type traps do not employ baits or scent, although they are occasionally helpful. In some states it is illegal to use bait or scent.

Several other types of traps can be used, including basket/suitcase type live traps. These are rarely used, however, except by professionals in urban areas where anti-trap sentiment or other reasons prevent the killing of beavers. These traps are difficult and cumbersome to use, and will not be further discussed here for use in beaver damage control. Any type of traps used for beavers or other animals should be checked daily.

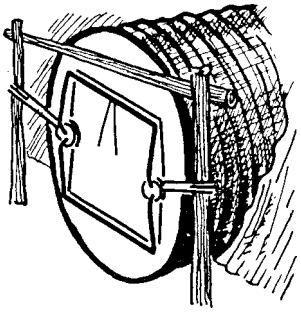
Snaring can be a very cost-effective method for capturing beavers. Snaring equipment costs far less than trapping equipment and is more convenient to use in many situations. In addition, beavers can be captured alive by snaring and released elsewhere if desired.

Snare placement is similar to trap placement. First, look for runways and fresh sign that indicate where beaver activities are focused. Find a suitable anchor such as a large tree, log, or root within 10 feet (3 m) of the runway where the snare will be set. If necessary, anchor snares by rods driven into the ground, but this is more time consuming and less secure. Attach three 14-gauge wires to the anchor so that each can swivel freely. Cut each wire to length so they reach about 1 foot (30 cm) past the runway. Twist the wires together to form a strong braided anchor cable. Drive a supporting stake into the ground near the runway and wrap the free end of the anchor cable around it twice. Prepare a new, dyed, No. 4 beaver or coyote snare, consisting of 42 inches (107 cm) of 3/32-inch (2.4-mm) steel cable with an attached wire swivel and slide lock. Twist the free ends of the three anchor wires around the wire swivel on the end of

the snare cable. Wrap the longest anchor wire around the base of the wire swivel and crimp it onto the snare cable about 2 inches (5 cm) from the swivel. Use both the stake and the supporting anchor wire to suspend a full-sized loop about 4 inches (10 cm) above the runway. If necessary, use guide sticks or other natural debris to guide beaver into the snare.

The described snare set is very common, but there are several variations and sets that can be used. Snares are frequently placed under logs, near bank dens, and next to castor mounds. Drowning sets can be made using underwater anchors, slide cables, and slide locks.

Fig. 14. Conibear® in culvert set. When beavers are stopping up a drainage culvert, (1) clean out the pipe to get water flowing through freely; (2) set the trap at the level of the drain pipe entrance, but far enough away to clear the culvert when the beaver enters; (3) put stakes on either side to make the beaver enter the trap correctly.



Snares should be checked at least every 24 hours. Dispatch snared beavers with a sharp blow or shot to the head. Beavers can be chemically immobilized and transported to suitable sites for release if desired.

Snares must be used with great care to avoid capturing nontarget animals. Avoid trails or areas that are used by livestock, deer, or dogs. Check with your local wildlife agency for regulations associated with trapping and snaring. Snaring is not allowed in some states.

For more information about the use of snares see *A Guide to Using Snares for Beaver Capture* (Weaver et al. 1985) listed at the end of this chapter.

Shooting

In some states, because of the extent of damage caused by beavers, regulations have been relaxed to allow shooting. Some states even allow the use of a light at night to spot beavers while shooting. Before attempting to shoot beavers, check regulations, and if applicable, secure permits and notify local law enforcement personnel of your intentions.

Beavers are most active from late afternoon to shortly after daybreak, depending on the time of year. They usually retire to a lodge or bank den for the day. Therefore, if night shooting is not permitted, the early evening and early morning hours are most productive. Choice of weapons depends on the range and situation. Most shooting is done with a shotgun at close range at night. Shooting alone is generally not effective in eliminating all beaver damage in an area. It can, however, be used to quickly reduce a population.

Other Methods

Because of the frustration and damage beavers have caused landowners, almost every control method imaginable has been tried. These range from dynamiting lodges during midday to using snag-type fish hooks in front of dams, road culverts, and drain pipes. Such methods rarely solve a damage problem, although they may kill a few beavers and nontarget species. They are not recommended by responsible wildlife professionals. One method used occasionally along streams prone to flooding is shooting beavers that have been flooded out of lodges and bank dens. This method is often dangerous and rarely solves a damage problem.

Economics of Damage and Control

The economics of beaver damage is somewhat dependent on the extent of the damage before it has been discovered. Some beaver damage problems are *intensive*, such as damage caused by one or two beavers in a new pond, damming or stopping up a culvert or drain pipe, flooding roads, or crops. Other problems are *extensive*, such as several beaver colonies in a flatland area, responsible for the flooding of several hundred acres of marketable timber that will die unless the water is removed quickly. Generally speaking, if a culvert or drain pipe can be unstopped, a knowledgeable trapper can remove one or two beavers in a night or two and eliminate further damage in an intensive damage situation (Fig. 14). However, an extensive situation may require a concentrated effort with several trappers, dynamiting or pulling dams, and a month or more of trapping to get the water off the timber and reduce further timber losses.

Economic damage is estimated to have exceeded $40 billion in the Southeastern United States during a recent 40-year period (Arner and Dubose 1982). This would include all damage to crops, forests, roads, pastures, and other rural and urban properties.

Economically, one must assess the situation and weigh the tradeoffs: the potential loss of thousands of board feet of timber and years of regeneration versus the cost of trapping. The cost of a couple of nights' trapping and a half-day of labor to clear the culverts is much less than the cost of rebuilding a washed-out road or losing flooded crops or timber.

The most important point is that damage control should begin as soon as it is evident that a beaver problem exists or appears likely to develop. Once beaver colonies become well established over a large contiguous area, achieving control is difficult and costly. One of the most difficult situations arises when an adjacent landowner will not allow the control of beavers on their property. In this situation, one can expect periodic reinvasions of beavers and continual problems with beaver damage, even if all beavers are removed from the property where control is practiced.

Although benefits of beavers and beaver ponds are not covered in depth here, there are a number. Aside from creating fish, waterfowl, furbearer, shorebird, reptile, and amphibian habitat, the beaver in many areas is an important fur resource, as well as a food resource. For those who have not yet tried it, beaver meat is excellent table fare if properly prepared, and it can be used whether the pelts are worth skinning or not. It also makes good bait for trapping large predators.

Proper precautions, such as wearing rubber gloves, should be taken when skinning or eviscerating beaver carcasses, to avoid contracting transmissible diseases such as tuleremia.

Acknowledgments

The authors thank, for their cooperation, past and present employees of the Fish and Wildlife Service, US Department of the Interior, county extension agents with the Cooperative Extension Service in various states, cooperators with the USDA-APHIS-ADC program in a number of states, and the many landowners with beaver problems across the South. The experience gained in efforts to assist landowners with wildlife damage problems provided most of the information contained herein.

Figures 1, 2, 4 and 5 from Schwartz and Schwartz (1981).

Figure 3 by Jill Sack Johnson.

Figure 6 and 7 by the authors.

Figures 8 through 12 and 14 from Miller (1978).

Figure 13 by Jill Sack Johnson after Miller (1978).

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

David E. Williams
State Director
USDA-APHIS-
Animal Damage Control
Lincoln, Nebraska 68501

Robert M. Corrigan
Staff Specialist
Vertebrate Pest Management
Purdue University
West Lafayette, Indiana 47907

CHIPMUNKS

Fig. 1. Eastern chipmunk, *Tamias striatus*

Damage Prevention and Control Methods

Exclusion

Rodent-proof construction will exclude chipmunks from structures.

Use 1/4-inch (0.6-cm) mesh hardware cloth to exclude chipmunks from gardens and flower beds.

Habitat Modification

Store food items, such as bird seed and dog food, in rodent-proof containers.

Ground covers, shrubs, and wood piles should not be located adjacent to structure foundations.

Frightening

Not effective.

Repellents

Area repellents. Naphthalene (moth flakes or moth balls) may be effective if liberally applied in confined places.

Taste repellents. Repellents containing bitrex, thiram, or ammonium soaps of higher fatty acids applied to flower bulbs, seeds, and vegetation (not for human consumption) may control feeding damage.

Toxicants

None are federally registered. Check with local extension agents or a USDA-APHIS-ADC personnel for possible Special Local Needs 24(c) registrations.

Fumigants

Generally impractical.

Trapping

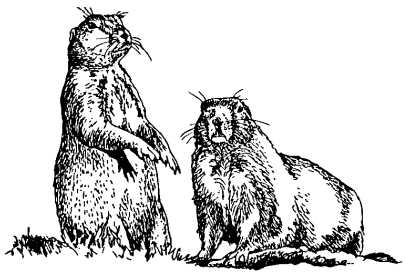
Rat-sized snap traps.

Live (box or cage) traps.

Glue boards.

Shooting

Small gauge shotguns or .22-caliber rifles.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

Identification

Fifteen species of native chipmunks of the genus *Eutamias* and one of the genus *Tamias* are found in North America. The eastern chipmunk *(Tamias striatus)* and the least chipmunk *(Eutamias minimas)*, discussed here, are the two most widely distributed and notable species. Behavior and damage is similar among all species of native chipmunks. Therefore, damage control recommendations are similar for all species.

The eastern chipmunk is a small, brownish, ground-dwelling squirrel. It is typically 5 to 6 inches (13 to 15 cm) long and weighs about 3 ounces (90 g). It has two tan and five blackish longitudinal stripes on its back, and two tan and two brownish stripes on each side of its face. The longitudinal stripes end at the reddish rump. The tail is 3 to 4 inches (8 to 10 cm) long and hairy, but it is not bushy (Fig. 1).

The least chipmunk is the smallest of the chipmunks. It is typically 3 2/3 to 4 1/2 inches (9 to 11 cm) long and weighs 1 to 2 ounces (35 to 70 g). The color varies from a faint yellowish gray with tawny dark stripes (Badlands, South Dakota) to a grayish tawny brown with black stripes (Wisconsin and Michigan). The stripes, however, continue to the base of the tail on all least chipmunks.

Chipmunks are often confused with thirteen-lined ground squirrels *(Spermophilus tridecemlineatus),* also called "striped gophers," and red squirrels *(Tamiasciurus hudsonicus).* The thirteen-lined ground squirrel is yellowish, lacks the facial stripes, and its tail is not as hairy as the chipmunk's. As this squirrel's name implies, it has 13 stripes extending from the shoulder to the tail on each side and on its back. When startled, a ground squirrel carries its tail horizontally along the ground; the chipmunk carries its tail upright. The thirteen-lined ground squirrel's call sounds like a high-pitched squeak, whereas chipmunks have a rather sharp "chuck-chuck-chuck" call. The red squirrel is very vocal and has a high-pitched chatter. It is larger than the chipmunk, has a bushier tail and lacks the longitudinal stripes of the chipmunk. Red squirrels spend a great deal of time in trees, while chipmunks spend most of their time on the ground, although they can climb trees.

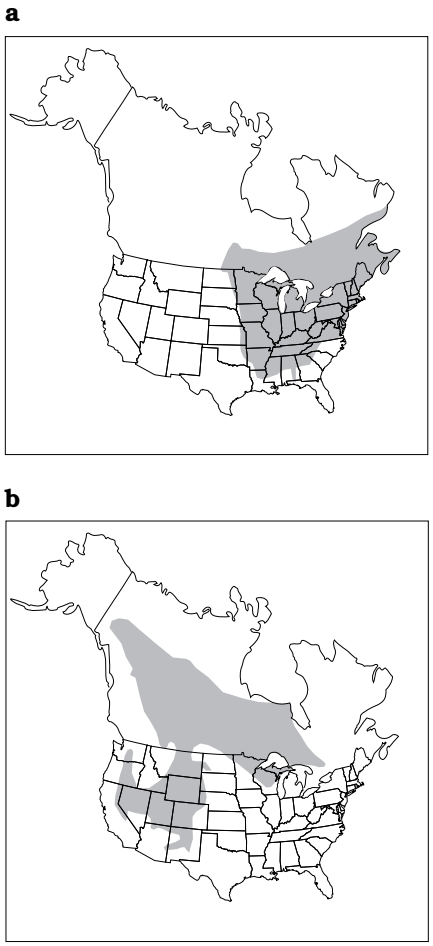


Fig. 2. Range of the eastern (a) and least chipmunk (b) in North America.

Range

The eastern chipmunk's range includes most of the eastern United States. The least chipmunk's range includes most of Canada, the US Rocky Mountains, the Great Basin, and parts of the upper Midwest (Fig. 2).

Habitat and General Biology

Eastern chipmunks typically inhabit mature woodlands and woodlot edges, but they also inhabit areas in and around suburban and rural homes. Chipmunks are generally solitary except during courtship or when rearing young.

The least chipmunk inhabits low sagebrush deserts, high mountain coniferous forests, and northern mixed hardwood forests.

The home range of a chipmunk may be up to 1/2 acre (0.2 ha), but the adult only defends a territory about 50 feet (15.2 m) around the burrow entrance. Chipmunks are most active during the early morning and late afternoon.

Chipmunk burrows often are well-hidden near objects or buildings (for example, stumps, wood piles or brush piles, basements, and garages). The burrow entrance is usually about 2 inches (5 cm) in diameter. There are no obvious mounds of dirt around the entrance because the chipmunk carries the dirt in its cheek pouches and scatters it away from the burrow, making the burrow entrance less conspicuous.

In most cases, the chipmunk's main tunnel is 20 to 30 feet (6 m to 9 m) in length, but complex burrow systems occur where cover is sparse. Burrow systems normally include a nesting chamber, one or two food storage chambers, various side pockets connected to the main tunnel, and separate escape tunnels.

With the onset of cold weather, chipmunks enter a restless hibernation and are relatively inactive from late fall through the winter months. Chipmunks do not enter a deep hibernation as do ground squirrels, but rely on the cache of food they have brought to their burrow. Some individuals become active on warm, sunny days during the winter. Most chipmunks emerge from hibernation in early March.

Eastern chipmunks mate two times a year, during early spring and again during the summer or early fall. There is a 31-day gestation period. Two to 5 young are born in April to May and again in August to October. The young are sexually mature within 1 year. Adults may live up to 3 years.

Adult least chipmunks mate over a period of 4 to 6 weeks from April to mid-July. Least chipmunks produce 1 litter of 2 to 7 young in May or June. Occasionally a second litter is produced in the fall.

Chipmunk pups appear above ground when they are 4 to 6 weeks old — 2/3 the size of an adult. Young will leave the burrow at 6 to 8 weeks.

Population densities of chipmunks are typically 2 to 4 animals per acre (5 to 10/ha). Eastern chipmunk population densities may be as high as 10 animals per acre (24/ha), however, if sufficient food and cover are available. Home ranges often overlap among individuals.

Food Habits

The diet of chipmunks consists primarily of grains, nuts, berries, seeds, mushrooms, insects, and carrion. Although chipmunks are mostly ground-dwelling rodents, they regularly climb trees in the fall to gather nuts, fruits, and seeds. Chipmunks cache food in their burrows throughout the year. By storing and scattering seeds, they promote the growth of various plants.

Chipmunks also prey on young birds and bird eggs. Chipmunks themselves serve as prey for several predators.

Damage and Damage Identification

Throughout their North American range, chipmunks are considered minor agricultural pests. Most conflicts with chipmunks are nuisance problems. When chipmunks are present in large numbers they can cause structural damage by burrowing under patios, stairs, retention walls, or foundations. They may also consume flower bulbs, seeds, or seedlings, as well as bird seed, grass seed, and pet food that is not stored in rodent-proof storage containers. In New England, chipmunks and tree squirrels cause considerable damage to maple sugar tubing systems by gnawing the tubes.

Legal Status

Chipmunks are not protected by federal law, but state and local regulations may apply. Most states allow landowners or tenants to take chipmunks when they are causing or about to cause damage. Some states, (for example, Georgia, North Carolina, and Arkansas) require a permit to kill nongame animals. Other states are currently developing laws to protect all nongame species. Consult your local conservation agency or USDA-APHIS-ADC personnel for the legal status of chipmunks in your state.

Damage Prevention and Control

Exclusion

Chipmunks should be excluded from buildings wherever possible. Use hardware cloth with 1/4-inch (0.6-cm) mesh, caulking, or other appropriate materials to close openings where they could gain entry.

Hardware cloth may also be used to exclude chipmunks from flower beds. Seeds and bulbs can be covered by 1/4-inch (0.6-cm) hardware cloth and the cloth itself should be covered with soil. The cloth should extend at least 1 foot (30 cm) past each margin of the planting. Exclusion is less expensive in the long run than trapping, where high populations of chipmunks exist.

Cultural Methods and Habitat Modifications

Landscaping features, such as ground cover, trees, and shrubs, should not be planted in continuous fashion connecting wooded areas with the foundations of homes. They provide protection for chipmunks that may attempt to gain access into the home. It is also difficult to detect chipmunk burrows that are adjacent to foundations when wood piles, debris, or plantings of ground cover provide above-ground protection.

Place bird feeders at least 15 to 30 feet (5 to 10 m) away from buildings so spilled bird seed does not attract and support chipmunks near them.

Repellents

Naphthalene flakes ("moth flakes") may repel chipmunks from attics, summer cabins, and storage areas when applied liberally (4 to 5 pounds of naphthalene flakes per 2,000 square feet [1.0 to 1.2 kg/100 m^2]). Use caution, however, in occupied buildings, as the odor may also be objectionable or irritating to people or pets.

There are currently no federally registered repellents for controlling rodent damage to seeds, although some states have Special Local Needs 24(c) registrations for this purpose. Taste repellents containing bitrex, thiram, or ammonium soaps of higher fatty acids can be used to protect flower bulbs, seeds, and foliage not intended for human consumption. Multiple applications of repellents are required. Repellents can be expensive and usually do not provide 100% reduction in damage to horticultural plantings.

Toxicants

There are no toxic baits registered for controlling chipmunks. Baits that are used against rats and mice in and around homes will also kill chipmunks although they are not labeled for such use and cannot be recommended. Moreover, chipmunks that die from consuming a toxic bait inside structures may create an odor problem for several days. Some states have Special Local Needs 24(c) registrations for chipmunk control for site-specific use.

Consult a professional pest control operator or USDA-APHIS-ADC biologist if chipmunks are numerous or persistent.

Fumigants

Fumigants are generally ineffective because of the difficulty in locating the openings to chipmunk burrows and because of the complexity of burrows.

Aluminum phosphide is a Restricted Use Pesticide that is registered in many states for the control of burrowing rodents. It is available in a tablet form, which when dropped into the burrow reacts with the moisture in the soil and generates toxic phosphine gas.

Aluminum phosphide, however, cannot be used in, under, or even near occupied buildings because there is a danger of the fumigant seeping into buildings.

Gas cartridges are registered for the control of burrowing rodents and are available from garden supply centers, hardware stores, seed catalogs, or the USDA-APHIS-ADC program. Chipmunk burrows may have to be enlarged to accommodate the commercially or federally produced gas cartridges. Gas cartridges should not be used under or around buildings or near fire hazards since they burn with an open flame and produce a tremendous amount of heat. Carbon monoxide and carbon dioxide gases are produced while the cartridges burn; thus, the rodents die from asphyxiation.

Trapping

Trapping is the most practical method of eliminating chipmunks in most home situations. Live-catch wire-mesh traps or common rat snap traps can be used to catch chipmunks. Common live-trap models include the Tomahawk (Nos. 102, 201) and Havahart (Nos. 0745, 1020, 1025) traps. Check the **Supplies and Materials** section for additional manufacturers of live-catch traps.

A variety of baits can be used to lure chipmunks into live traps, including peanut butter, nutmeats, pumpkin or sunflower seeds, raisins, prune slices, or common breakfast cereal grains. Place the trap along the pathways where chipmunks have been seen frequently. The trap should be securely placed so there is no movement of the trap prematurely when the animal enters. Trap movement may prematurely set off the trap and scare the chipmunk away. A helpful tip is to "prebait" the trap for 2 to 3 days by wiring the trap doors open. This will condition the chipmunk to associate the new metal object in its territory with the new free food source. Set the trap after the chipmunk is actively feeding on the bait in and around the trap. Live traps can be purchased from local hardware stores, department stores, pest control companies, or rented from local animal shelters.

Check traps frequently to remove captured chipmunks and release any nontarget animals caught in them. Avoid direct contact with trapped chipmunks. Transport and release live-trapped chipmunks several miles from the point of capture (in areas where they will not bother someone else), or euthanize by placing in a carbon dioxide chamber.

Common rat snap traps can be used to kill chipmunks if these traps are isolated from children, pets, or wildlife. They can be set in the same manner as live traps but hard baits should be tied to the trap trigger. Prebait snap traps by not setting the trap until the animal has been conditioned to take the bait without disturbance for 2 to 3 days. Small amounts of extra bait may be placed around the traps to make them more attractive. Set the snap traps perpendicular to the chipmunk's pathway or in pairs along travel routes with the triggers facing away from each other. Set the trigger arm so that the trigger is sensitive and easily sprung.

To avoid killing songbirds in rat snap traps, it is advisable to place the traps under a small box with openings that allow only chipmunks access to the baited trap. The box must allow enough clearance so the trap operates properly. Conceal snap traps that are set against structures by leaning boards over them. Small amounts of bait can be placed at the openings as an attractant.

Shooting

Where shooting is legal, use a small-gauge shotgun or a .22-caliber rifle with bird shot or C.B. cap loads. Chipmunks are nervous and alert, so they make difficult targets. The best time to attempt shooting is on bright sunny days during the early morning.

Economics of Damage and Control

The majority of chipmunk damage involves minimal economic loss (under $200). Homeowners report that chipmunks are quite destructive when it comes to their burrowing activities around structures. This damage warrants an investment in control to protect structural integrity of stairs, patios, and foundations. Their consumption of seeds, flower bulbs, fruit, and vegetables is often a nuisance.

Acknowledgments

We would like to thank all the USDA-APHIS-ADC wildlife biologists who provided information on chipmunks pertinent to their locality. Kathleen LeMaster and Dee Anne Gillespie provided technical assistance.

Figure 1 from Schwartz and Schwartz (1981).

Figure 2 from Burt and Grossenheider (1976).

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Ronald M. Case
Professor of Wildlife Biology
Department of Forestry, Fisheries and Wildlife
University of Nebraska
Lincoln, Nebraska 68583-0819

Bruce A. Jasch
Research Assistant
Department of Forestry, Fisheries and Wildlife
University of Nebraska
Lincoln, Nebraska 68583-0819

POCKET GOPHERS

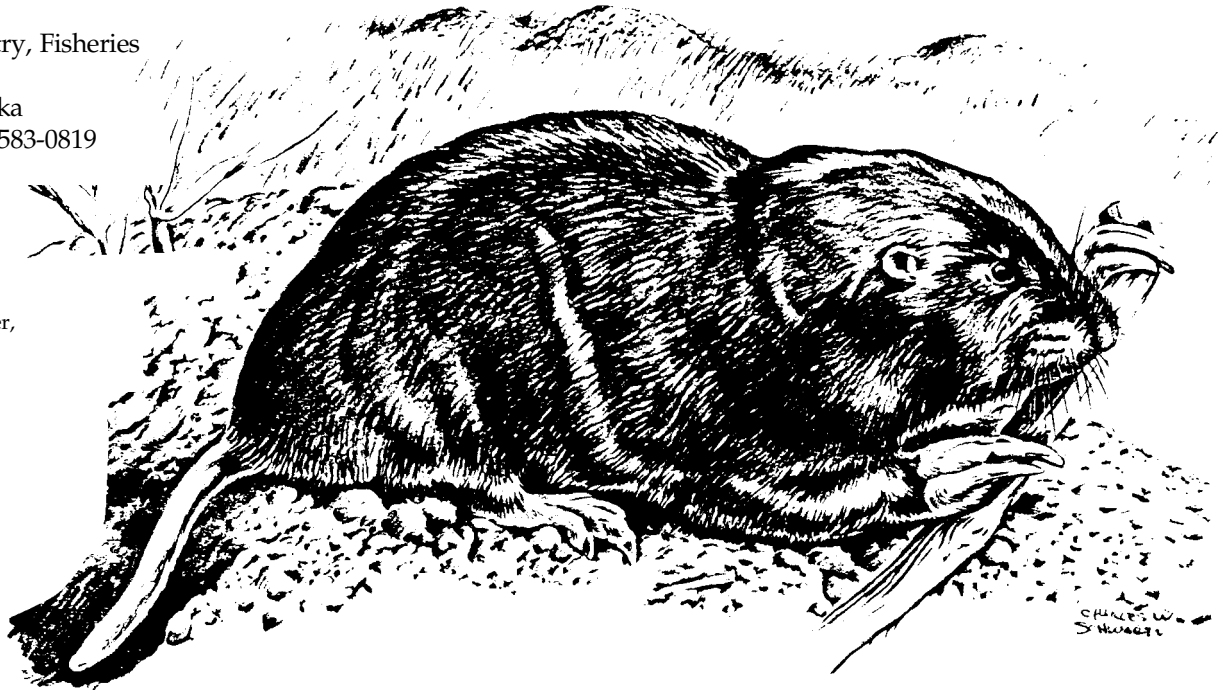


Fig. 1. Plains pocket gopher, *Geomys bursarius*

Damage Prevention and Control Methods

Exclusion

Generally not practical.

Small mesh wire fence may provide protection for ornamental trees and shrubs or flower beds.

Plastic netting protects seedlings.

Cultural Methods

Damage resistant varieties of alfalfa.

Crop rotation.

Grain buffer strips.

Control of tap-rooted forbs.

Flood irrigation.

Plant naturally resistant varieties of seedlings.

Repellents

Synthetic predator odors are all of questionable benefit.

Toxicants

Baits:

Strychnine alkaloid.

Zinc phosphide.

Chlorophacinone.

Diphacinone.

Fumigants:

Carbon monoxide from engine exhaust.

Others are not considered very effective, but some are used:
Aluminum phosphide.
Gas cartridges.

Trapping

Various specialized gopher kill traps.

Common spring or pan trap (sizes No. 0 and No. 1).

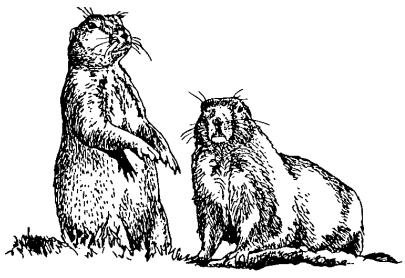
Shooting

Not practical.

Other

Buried irrigation pipe or electrical cables can be protected with cylindrical pipe having an outside diameter of at least 2.9 inches (7.4 cm).

Surrounding a buried cable with 6 to 8 inches (15 to 20 cm) of coarse gravel (1 inch [2.5 cm] in diameter) may provide some protection.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

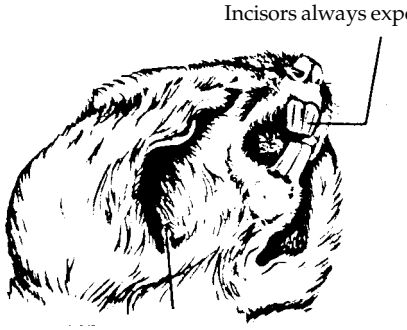


Fig. 2. Pocket gopher characteristics.

Identification

Pocket gophers (Fig. 1) are fossorial (burrowing) rodents, so named because they have fur-lined pouches outside of the mouth, one on each side of the face (Fig. 2). These pockets, which are capable of being turned inside out, are used for carrying food. Pocket gophers are powerfully built in the forequarters and have a short neck; the head is fairly small and flattened. The forepaws are large-clawed and the lips close behind their large incisors, all marvelous adaptations to their underground existence.

Gophers have small external ears and small eyes. As sight and sound are severely limited, gophers are highly dependent on the sense of touch. The vibrissae (whiskers) on their face are very sensitive to touch and assist pocket gophers while traveling about in their dark tunnels. The tail is sparsely haired and also serves as a sensory mechanism guiding gophers' backward movements. The tail is also important in thermoregulation, acting as a radiator.

Pocket gophers are medium-sized rodents ranging from about 5 to nearly 14 inches (13 to 36 cm) long (head and body). Adult males are larger than adult females. Their fur is very fine, soft, and highly variable in color. Colors range from nearly black to pale brown to almost white. The great variability in size and color of pocket gophers is attributed to their low dispersal rate and thus limited gene flow, resulting in adaptation to local conditions.

Thirty-four species of pocket gophers, represented by five genera, occupy the western hemisphere. In the United States there are 13 species and three genera. The major features differentiating these genera are the size of their forefeet, claws, and front surfaces of their chisel-like incisors (Fig. 3).

Thomomys have smooth-faced incisors and small forefeet with small claws. Northern pocket gophers (*Thomomys talpoides*) are typically from 6 1/2 to 10 inches (17 to 25 cm) long. Their fur is variable in color but is often yellowish brown with pale underparts. Botta's (or valley) pocket gophers (*Thomomys bottae*) are extremely variable in size and color. Botta's pocket gophers are 5 inches to about 13 1/2 inches (13 to 34 cm) long. Their color varies from almost white to black.

Geomys have two grooves on each upper incisor and large forefeet and claws. Plains pocket gophers (*Geomys bursarius*) vary in length from almost 7 1/2 to 14 inches (18 to 36 cm). Their fur is typically brown but may vary to black. Desert pocket gophers (*Geomys arenarius*) are always brown and vary from nearly 8 3/4 to 11 inches (22 to 28 cm) long. Texas pocket gophers (*Geomys personatus*) are also brown and are from slightly larger than 8 3/4 to nearly 13 inches (22 to 34 cm) long. Southeastern pocket gophers (*Geomys pinetis*) are of various shades of brown, depending on soil color, and are from 9 to 13 1/4 inches (23 to 34 cm) long.

Pappogeomys have a single groove on each upper incisor and, like *Geomys*, have large forefeet with large claws. Yellow-faced pocket gophers (*Pappogeomys castanops*) vary in length from slightly more than 5 1/2 to just less than 7 1/2 inches (14 to 19 cm). Their fur color varies from pale yellow to dark reddish brown. The underparts vary from whitish to bright yellowish buff. Some hairs on the back and top of the head are dark-tipped.

Range

Pocket gophers are found only in the Western Hemisphere. They range from Panama in the south to Alberta in the north. With the exception of the southeastern pocket gopher, they occur throughout the western two-thirds of the United States.

Fig. 3. These three genera of pocket gophers can be differentiated by relative size of forefeet and front surfaces of upper incisors.

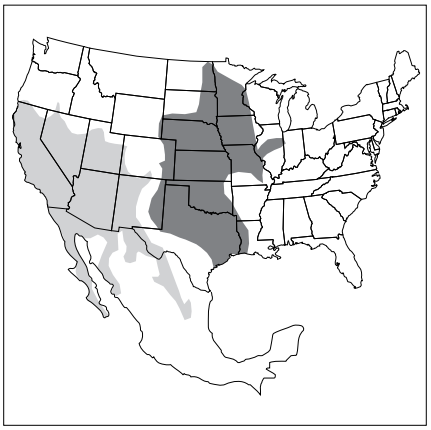


Fig. 4a. Range of the plains pocket gopher (*Geomys bursarius*) (dark) and Botta's pocket gopher (*Thomomys bottae*) (light) in North America.

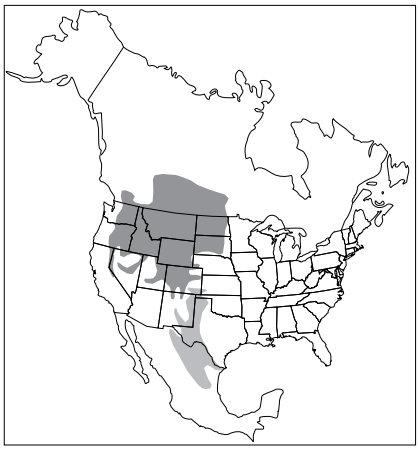


Fig. 4b. Range of the northern pocket gopher (*Thomomys talpoides*) (dark) and yellow-faced pocket gopher (*Pappogeomys castanops*) (light) in North America.

Fig. 4c. Range of the southeastern pocket gopher (*Geomys pinetis)* (dark) and southern pocket gopher (*Thomomys umbrinus*) (light) in North America.

Plains pocket gophers (*Geomys bursarius*, Fig. 4a) are found in the central plains from Canada south through Texas and Louisiana. Botta's (or valley) pocket gophers (*Thomomys bottae*, Fig. 4a) are found in most of the southern half of the western United States.

Northern pocket gophers (*Thomomys talpoides*, Fig. 4b) range throughout most of the states in the northern half of the western United States. Yellow-faced pocket gophers (*Pappogeomys castanops*, Fig. 4b) occur from Mexico, along the western edge of Texas, eastern New Mexico, southeastern Colorado, southwestern Kansas, and into the panhandle of Oklahoma.

Southeastern pocket gophers (*Geomys pinetis*, Fig. 4c) are found in northern and central Florida, southern Georgia, and southeastern Alabama. Southern pocket gophers (*Thomomys umbrinus*, Fig. 4c) range primarily in Central America, but occur in extreme southwestern New Mexico and southeastern Arizona. Desert pocket gophers (*Geomys arenarius*) occur only in southwestern New Mexico and the extreme western edge of Texas. Mazama pocket gophers (*Thomomys mazama*,), mountain pocket gophers (*Thomomys monticola*), and Camas pocket gophers (*Thomomys bulbivorus*) have more limited distributions in the extreme western United States.

Habitat

A wide variety of habitats are occupied by pocket gophers. They occur from low coastal areas to elevations in excess of 12,000 feet (3,600 m). Pocket gophers similarly are found in a wide variety of soil types and conditions. They reach their greatest densities on friable, light-textured soils with good herbage production, especially when that vegetation has large, fleshy roots, bulbs, tubers, or other underground storage structures.

The importance of soil depth and texture to the presence or absence of gophers is both obvious and cryptic. Shallow soils may be subject to cave-ins and thus will not maintain a tunnel. Tunnels are deeper in very sandy soils where soil moisture is sufficient to maintain the integrity of the burrow. A less visible requirement is that atmospheric and exhaled gases must diffuse through the soil to and from the gopher's tunnel. Thus light-textured, porous soils with good drainage allow for good gas exchange between the tunnel and the atmosphere. Soils that have a very high clay content or those that are continuously wet diffuse gases poorly and are unsuitable for gophers.

Pocket gophers sometimes occupy fairly rocky habitats, although those habitats generally do not have more than 10% rocks in the top 8 inches (20 cm) of soil. Pocket gophers appear to burrow around rocks greater than 1 inch (2.5 cm) in diameter, but smaller rocks are frequently pushed to the surface.

Soil depth is also important in ameliorating temperatures. Soils less than 4 inches (10 cm) deep probably are too warm during summers. Shallow tunnels may also limit the presence of gophers during cold temperatures, especially if an insulating layer of snow is absent.

Typically, only one species of pocket gopher is found in each locality. Soil factors are important in limiting the distributions of pocket gophers. The larger gophers are restricted to sandy and silty soils east of the Rockies. Smaller gophers of the genus *Thomomys* have a broader tolerance to various soils.

Food Habits

Pocket gophers feed on plants in three ways: 1) they feed on roots that they encounter when digging; 2) they may go to the surface, venturing only a body length or so from their tunnel opening to feed on aboveground vegetation; and 3) they pull vegetation into their tunnel from below. Pocket gophers eat forbs, grasses, shrubs, and trees. They are strict herbivores, and any animal material in their diet appears to result from incidental ingestion.

Alfalfa and dandelions are apparently some of the most preferred and nutri-

tious foods for pocket gophers. Generally, *Thomomys* prefer perennial forbs, but they will also eat annual plants with fleshy underground storage structures. Plains pocket gophers consume primarily grasses, especially those with rhizomes, but they seem to prefer forbs when they are succulent in spring and summer.

Portions of plants consumed also vary seasonally. Gophers utilize aboveground portions of vegetation mostly during the growing season, when the vegetation is green and succulent. Height and density of vegetation at this time of year may also offer protection from predators, reducing the risk of short surface trips. Year-round, however, roots are the major food source. Many trees and shrubs are clipped just above ground level. This occurs principally during winter under snow cover. Damage may reach as high as 10 feet (3 m) above ground. Seedlings also have their roots clipped by pocket gophers.

General Biology, Reproduction, and Behavior

Just as cheek pouches are used in identification of pocket gophers, their fan-shaped soil mounds are characteristic evidence of their presence. Typically, there is only one gopher per burrow system. Obvious exceptions are when mating occurs and when the female is caring for her young.

All pocket gophers use their claws and teeth while digging. *Geomys*, however, are primarily claw diggers, while *Thomomys* do much more tooth digging, and *Pappogeomys* are intermediate between the two. Soil, rocks, and other items loosened by this means are kicked away from the digging area with the hind feet. Gophers then turn over, making a sort of somersault within the confines of their burrow, and use their forefeet and chest to push the materials out of the burrow.

The incisors of pocket gophers, as in all rodents, grow continuously to repair the wear and tear on the teeth. On the other hand, gophers must gnaw continuously to keep their teeth ground to an appropriate length. Gophers exert tremendous pressure with their bite, up to 18,000 pounds per square inch (1,265 kg/cm^2).

Burrow systems consist of a main burrow, generally 4 to 18 inches (10 to 46 cm) below and parallel to the ground surface, with a variable number of lateral burrows off the main one. These end at the surface with a soil mound or sometimes only a soil plug. There are also deeper branches off the main burrow that are used as nests and food caches. Enlargements along the main tunnel are probably feeding and resting locations. Nest chambers have dried grasses and other grasslike plants formed into a sphere. The maximum depth of at least some portion of a burrow may be as great as 5 or 6 feet (1.5 or 1.8 m). The diameter of a burrow is about 3 inches (7.6 cm) but varies with the body size of the gopher.

Burrow systems may be linear or highly branched. The more linear systems may be those of reproductive males, since this shape would increase the likelihood of encountering a female's burrow. The number of soil mounds on the surface of the ground may be as great as 300 per animal in a year. Burrows are sometimes quite dynamic, with portions constantly being sealed off and new areas excavated. A single burrow system may contain up to 200 yards (180 m) of tunnels. The poorer the habitat, the larger the burrow system required to provide sufficient forage for its occupant.

The rate of mound building is highly variable. Estimates include an average of 1 to 3 per day up to 70 mounds per month. This activity brings large amounts of soil to the surface, variously estimated at 2 1/4 tons (2 mt) per gopher each year up to 46 3/4 tons per acre (103.9 mt/ha) for a population of 50 southern pocket gophers.

The tunnel system tells us much about its inhabitant. The system is rigorously defended against intruders and constitutes the home range of the pocket gopher, which may be up to 700 square yards (560 m^2).

Pocket gophers also tunnel through snow, above the ground. Soil from below ground is pushed into the snow tunnels, but mounds are not built. When the snow melts, the soil casts (tubes) remain on the ground until they weather away. Soil casts are left by both *Thomomys* and *Geomys* in areas where snow cover is adequate for burrowing.

Pocket gophers do not hibernate. Some observers believe their activities peak at dawn and dusk, but various studies have shown them to be active throughout the day, with activity periods interspersed with rest. Mound building by plains pocket gophers increases in spring, frequently declines during summer, and increases again in fall. In *Thomomys*, mound building increases from spring through summer into fall. Tunneling underground is a tremendously demanding activity estimated to require 360 to 3,400 times the energy of moving across the surface. Thus, this activity must be of great importance to the pocket gopher's survival, either increasing its chance of breeding or finding needed food resources.

Pocket gophers reach sexual maturity in the spring following their birth. In the northern part of their range they have 1 litter per year. In the southern portion they may have 2 litters per year. One researcher has suggested that *Thomomys* in irrigated alfalfa in California may breed throughout the year.

Litter sizes range from 1 to 10 but typically average 3 to 4. In some southern portions of their range where 2 litters are born each year, litter size is usually smaller, averaging about 2. The breeding season also varies, but births typically occur from March through June. The gestation period is 18 or 19 days for the northern pocket gopher, but periods as long as 51 days for the plains pocket gopher have been reported. Sex ratios are typically in favor of females, generally ranging from 55% to 60% females for *Geomys*. In *Thomomys,* the sex ratio is often 50:50 but it varies seasonally. There may be more males than females in spring and the reverse for summer and

fall. Pocket gophers have been thought to be polygamous (one male mating with two or more females), but serial monogamy may be the case. The male cohabits a tunnel system and may help care for young before moving on to another female's burrow system. Some researchers believe both sexes move mainly underground from their own to other burrows during the breeding season.

Densities reported for various pocket gophers are highly variable. Densities of 16 to 20 per acre (40 to 49/ha) are very common for *Thomomys,* but they may attain densities up to 62 per acre (153/ha). For *Geomys*, 6 to 8 per acre (20/ha) are representative of high densities. Average life span of gophers appears to change inversely with population density. Average longevity for *Thomomys* ranges from just over 1 year to nearly 3 years. *Geomys* may live to an average age of 2 and reach a maximum age in the wild in excess of 7 years.

Sharp declines in gopher populations have been noted on several occasions. Usually some climatic factor is associated with a marked decline. An example would be a heavy snow cover, then rapid snowmelt with a concomitant rise in the water table.

External parasites are often found on pocket gophers. Lice are perhaps the most common, while ticks, fleas, and mites also occur. The contribution of parasites to gopher mortality is unknown.

Numerous predators eat pocket gophers. Some of the predators pursue the gopher in its tunnel system (weasels, perhaps spotted skunks, and several snakes including gopher, bull, and rattlesnakes). Badgers are adept at digging out gophers, and a whole host of predators prey on gophers when they are aboveground feeding, dispersing, or while they construct their mounds. Other mammalian predators include coyotes, domestic dogs, foxes, house cats, striped skunks, and bobcats. Raptors that prey on gophers include several owls, especially great horned and barn owls, and several hawks.

A great diversity of vertebrates has been found in the burrows of pocket gophers. It is especially interesting to note how gophers react to those animals. Most amphibians and lizards are largely ignored. Ground squirrels, kangaroo rats, and smaller rodents generally avoid gophers, frequently leaving the tunnel system if occupied by a gopher. Sometimes gophers block the exit of these rodents by constructing earthen plugs in the burrow system. When pocket gophers encounter snakes, weasels, or other threats, they typically react by assuming a threatening posture with the mouth open, vocalizing with panting sounds, and raising the front of the body slightly with their claws extended forward. This behavior usually chases away other gophers in the tunnel. If the intruder is a snake, many strikes bounce off the gopher's incisors and claws. In addition, the gopher may try to block the intruder with a wall of soil.

Pocket gophers are capable of swimming. The southern pocket gopher has the greatest endurance of three species that were tested in laboratory conditions. The plains pocket gopher is intermediate in its endurance between the southern pocket gopher and the yellow-faced pocket gopher. The latter is a very poor swimmer. The superior swimming ability of the southern pocket gopher may be an adaptation to its mountain habitat, which frequently undergoes flooding during snowmelt. Swimming during flooding may also be a method of pocket gopher dispersal.

Dispersal of young plains pocket gophers from their natal burrows has been reported to begin in June in Colorado. Young apparently begin to disperse when they are only one-third the adult body size. Other indications of aboveground dispersal of pocket gophers have been reported by incidental captures of gophers in drift fences set for snakes. A plains pocket gopher was reported a victim of an automobile on a highway in Iowa, and plains pocket gophers are reported falling into window wells every summer in Nebraska. These aboveground movements are a prime reason for high mortality in densely populated areas.

Damage and Damage Identification

Several mammals are sometimes confused with pocket gophers because of variations in common local terminology (Fig. 5). In addition, in the southeastern United States, pocket gophers are called "salamanders," (derived from the term *sandy mounder*), while the term *gopher* refers to a tortoise. Pocket gophers can be distinguished from the other mammals by their telltale signs as well as by their appearance. Pocket gophers leave soil mounds on the surface of the ground. The mounds are usually fan-shaped and tunnel entrances are plugged, keeping various intruders out of burrows.

Damage caused by gophers includes destruction of underground utility cables and irrigation pipe, direct consumption and smothering of forage by earthen mounds, and change in species composition on rangelands by providing seedbeds (mounds) for invading annual plants. Gophers damage trees by stem girdling and clipping, root pruning, and possibly root exposure caused by burrowing. Gopher mounds dull and plug sicklebars when harvesting hay or alfalfa, and soil brought to the surface as mounds is more likely to erode. In irrigated areas, gopher tunnels can channel water runoff, causing loss of surface irrigation water. Gopher tunnels in ditch banks and earthen dams can weaken these structures, causing water loss by seepage and piping through a bank or the complete loss or washout of a canal bank. The presence of gophers also increases the likelihood of badger activity, which can also cause considerable damage.

Legal Status

Pocket gophers are not protected by federal or state law.

Damage Prevention and Control Methods

Exclusion

Because of the expense and limited practicality, exclusion is of little use. Fencing of highly valued ornamental shrubs or landscape trees may be justified. The fence should be buried at least 18 inches (46 cm). The mesh should be small enough to exclude gophers: 1/4-inch or 1/2-inch (6- to 13-mm) hardware cloth will suffice. Cylindrical plastic netting placed over the entire seedling, including the bare root, reduces damage to newly planted forest seedlings significantly.

Cultural Methods and Habitat Modification

These methods take advantage of knowledge of the habitat requirements of pocket gophers or their feeding behavior to reduce or eliminate damage.

Crop Varieties. In alfalfa, large taprooted plants may be killed or the vigor of the plant greatly reduced by pocket gophers feeding on the roots. Varieties with several large roots rather than a single taproot suffer less when gophers feed on them. Additionally, pocket gophers in alfalfa fields with fibrous-root systems may have smaller ranges. This would reduce gopher impact on yield.

Crop Rotation. There are many good reasons for using a crop rotation scheme, not the least of which is minimizing problems with pocket gophers. When alfalfa is rotated with grain crops, the resultant habitat is incapable of supporting pocket gophers. The annual grains do not establish large underground storage structures and thus there is insufficient food for pocket gophers to survive year-round.

Grain Buffer Strips. Planting 50-foot (15-m) buffer strips of grain around hay fields provides unsuitable habitat around the fields and can minimize immigration of gophers.

Weed Control. Chemical or mechanical control of forbs, which frequently have large underground storage structures, can be an effective method of minimizing damage by *Thomomys* to rangelands. It may also be effective in making orchards and shelterbelts less suitable for pocket gophers. The method is less effective for plains pocket gophers as they survive quite nicely on grasses. The warm-season prairie grasses have large root-to-stem ratios and these food sources are adequate for *Geomys*.

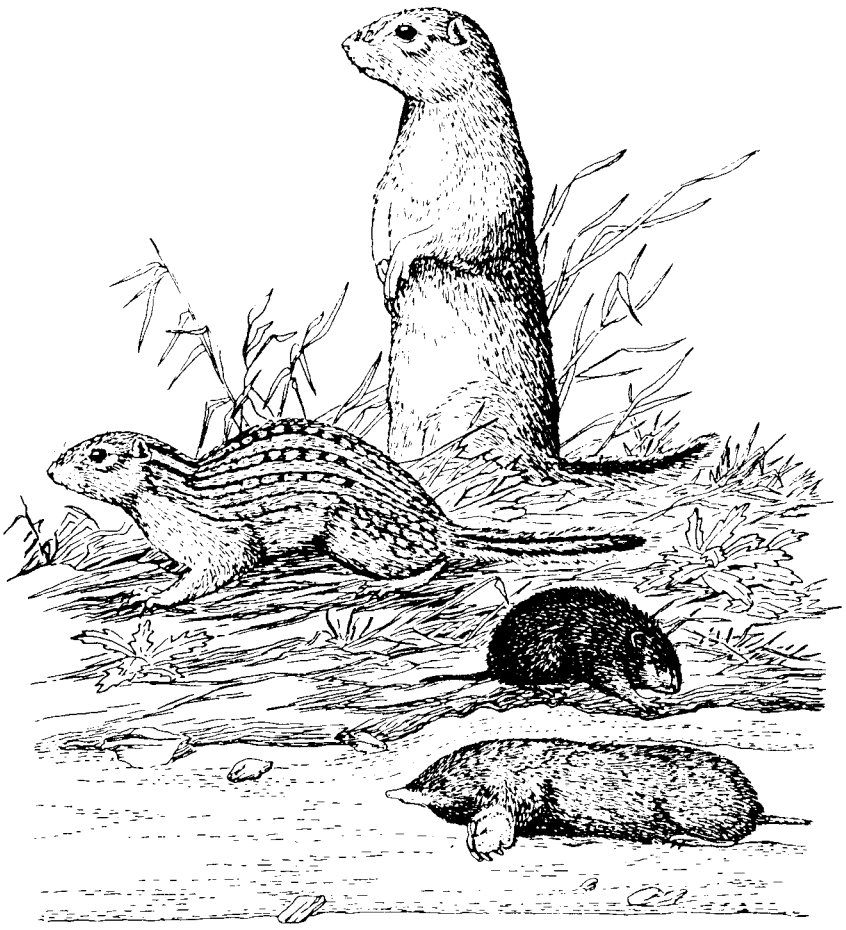


Fig. 5. Mammals that are sometimes called gophers. From top to bottom: Richardson ground squirrel, thirteen-lined ground squirrel, vole, and mole.

Flood Irrigation. Irrigating fields by flooding can greatly reduce habitat suitability for pocket gophers. Water can fill a gopher's tunnel, thus causing the occupant to drown or flee to the surface, making it vulnerable to predation. The soil may be so damp that it becomes sticky. This will foul the pocket gopher's fur and claws. As the soil becomes saturated with water, the diffusion of gases into and out of the gopher's burrow is inhibited, creating an inhospitable environment. The effectiveness of this method can be enhanced by removing high spots in fields that may serve as refuges during irrigation.

Damage-Resistant Plant Varieties. Tests of several provenances of ponderosa pine showed that some have natural resistance to gopher damage.

Repellents

Some predator odors have been tested as gopher repellents and show some promise. Commercially available sonic devises are claimed to repel pocket gophers. There is, however, no scientific supporting evidence. The plants known as caper spurge, gopher purge, or mole plant (*Euphorbia lathyrus*) and the castor-oil plant (*Ricinus communis*) have been promoted as gopher

repellents, but there is no evidence of their effectiveness. In addition, these are not recommended as they are both poisonous to humans and pets.

Toxicants

Several rodenticides currently are federally registered and available for pocket gopher control. The most widely used and evaluated is strychnine alkaloid (0.25 to 0.5% active ingredient) on grain baits. There is some concern that pocket gophers may consume sublethal doses of strychnine and then develop bait shyness. Strychnine acts very rapidly and gophers sometimes die within an hour after consuming a lethal dose. It is registered for use for *Geomys* spp. and *Thomomys* spp. If the label has directions for use with a burrow builder machine, then it is a Restricted Use Pesticide. Zinc phosphide (2%) is less effective than strychnine for gopher control. Anticoagulants now are available for pocket gopher control. Currently, the only federally registered products are chlorophacinone and diphacinone.

To poison pocket gophers, the bait must be placed in their tunnel systems by hand or by a special machine known as a burrow builder. Underground baiting for pocket gopher control with strychnine presents minimal hazards to nontarget wildlife, either by direct consumption of bait or by eating poisoned gophers. Poison bait spilled on the surface of the ground may be hazardous to ground-feeding birds such as mourning doves.

The main drawback to grain baits is their high susceptibility to decomposition in the damp burrows. A new product that contains a grain mixture plus the anticoagulant, diphacinone, in a paraffin block not only increases the bait's effective life, but also makes it possible for more than one gopher to be killed with the same bait. Once the resident gopher ingests the toxicant and dies, it is typical for a neighboring gopher to take over the tunnel system and thus to ingest the still-toxic bait.

Hand Baiting. Bait can be placed in a burrow system by hand, using a special hand-operated bait dispenser probe, or by making an opening to the burrow system with a probe. Placing bait in the burrow by hand is more time-consuming than either of the probing methods, but there is no doubt that the bait is delivered to the tunnel system.

The key to efficient and effective use of these methods is locating the burrow system. The main burrow generally is found 12 to 18 inches (30 to 46 cm) away from the plug on the fan-shaped mounds (Fig. 6). If you use a trowel or shovel to locate the main burrow, dig 12 to 18 inches (30 to 46 cm) away from the plug. When the main burrow is located, place a rounded tablespoon (15 ml) of bait in each direction. Place the bait well into each tunnel system with a long-handled spoon and then block off each tunnel with sod clumps and soil. Bait blocks are also applied in this manner. The reason for closing the burrow is that pocket gophers are attracted to openings in their system with the intent of closing them with soil. Thus, if there is a detectable opening near the placement of poison, the pocket gopher may cover the bait with soil as it plugs the opening. Pocket gophers normally travel all portions of their burrow system during a day.

Place a probe for pocket gopher tunnels where you expect to locate the main burrow as described above (plans for making a probe and instructions for use are presented in figure 7). You will know you have located a burrow by the decreased friction on the probe. With a reservoir-type bait probe dispenser (Fig. 8), a button is pushed when the probe is in a burrow and a metered dose of bait drops into the burrow. With the burrow probe (without a bait reservoir), make an opening from the surface of the ground to the burrow. Place about a tablespoon (15 ml) of bait down the probe opening. This method is much quicker than digging open the burrow tunnel. For best control, dose each burrow system in two or three places. Be sure to cover the probe hole with a sod clump so that the pocket gopher does not cover the bait when attracted to the opening in its burrow. Greater doses of chlorophacinone or other locally registered anticoagulants are recommended (1/2 cup [120 ml]) at each of two or three locations in each burrow. Also, since some gophers poisoned in this manner die aboveground, the area should be checked periodically for 10 to 14 days after treatment. Any dead gophers found should be buried or incinerated.

Mechanical Burrow Builder. The burrow builder (Fig. 9) delivers bait underground mechanically, so large areas can be economically treated for pocket gopher control. It is tractor-drawn and is available in hydraulically operated units or three-point hitch models.

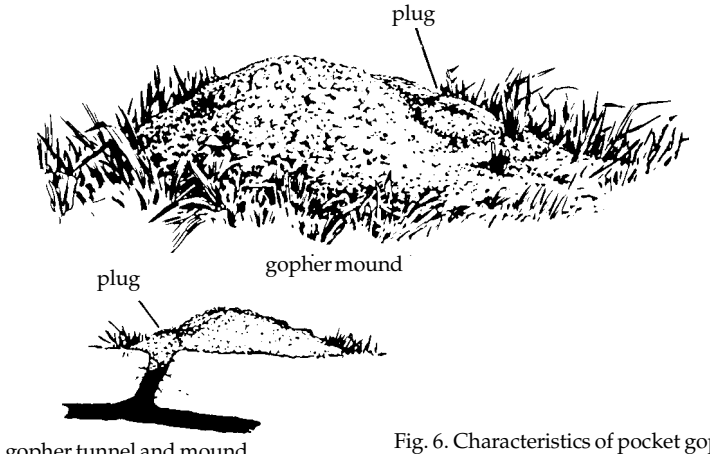
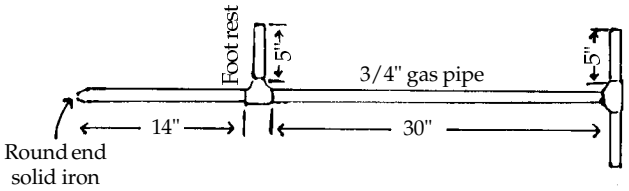


Fig. 6. Characteristics of pocket gopher mounds and relation to tunnel system.

Fig. 7. Materials and construction plans for pocket gopher probes.

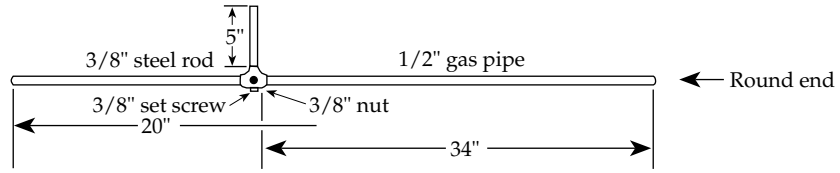
For extensive use in relatively soft soil, a durable probe may be made of 3/4-inch gas pipe—1 piece 30 inches long. The 30-inch piece is threaded at both ends and the other pieces at one end only. A piece of 1/2-inch round iron about 2 inches long is welded into the unthreaded end of the 14-inch pipe and bluntly pointed. The pieces are then arranged and fitted together with two 3/4-inch T-joints as shown here.



For use in hard soil, the probe may be made of the following materials:

1 piece of 1/2-inch galvanized pipe, 34 inches long
1 piece of 1/2-inch galvanized pipe, 5 inches long
1 1/2-inch galvanized T-joint
1 piece of 1/2-inch round iron, 2 inches long
1 piece of highly temperated steel, 3/8-inch in diameter and 28 inches long
1 3/8-inch set screw, 1 inch long
1 3/8-inch nut
1 reducer, 1/2 inch to 3/8 inch

The two pieces of pipe are each threaded at one end. The piece of round iron is welded into the unthreaded end of the 34-inch pipe and bluntly pointed. A 3/8-inch hole is bored in the T-joint, and the 3/8-inch nut is brazed over this hole to accommodate the set screw. The piece of highly tempered steel is sharply pointed on one or both ends and held in place by the set screw. The pointed end of a hayrake tooth cut 28 inches long would serve well for this piece. These materials are then assembled as shown here.



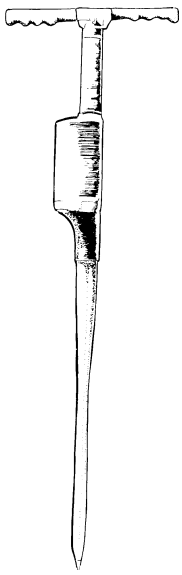


Fig. 8. Automatic bait dispensing probe for pocket gopher control.

The device consists of a knife and torpedo assembly that makes the artificial burrow at desired soil depths, a coulter blade that cuts roots of plants ahead of the knife, a seeder assembly for bait dispensing, and the packer wheel assembly to close the burrow behind the knife. The seeder box has a metering device for dispensing various toxic baits at desired rates.

The artificial burrows should be constructed at a depth similar to those constructed by gophers in your area. The artificial burrows may intercept the gopher burrows, or the gophers may inquisitively enter the artificial burrows, gather bait in their cheek pouches, and return to their burrow system to consume the bait. Recommended application rates of 1 to 2 pounds per acre (1.1 to 2.2 kg/ha) of 0.3 to 0.5% strychnine alkaloid grain should provide an 85% to 95% reduction in the gopher population (Table 1 demonstrates how to calculate bait delivery rates).

The burrows should be spaced at 20- to 25-foot (6- to 8-m) intervals. To assure success:

1. Operate the burrow builder parallel to the ground surface, at a depth where gophers are active. It is essential to check the artificial burrow. If the soil is too dry, a good burrow will not be formed; if the soil is too wet and sticky, soil will accumulate on packer wheels or even on the knife shank and the slot may not close adequately.
2. Check periodically to note whether bait is being dispensed. Sometimes the tube gets clogged with soil.
3. Encircle the perimeter of the field with artificial burrows to deter reinvasions.
4. Follow directions provided with the burrow builder machine.

It is especially important to scour the torpedo assembly by pulling it through sandy soils so that smooth burrows will be constructed.

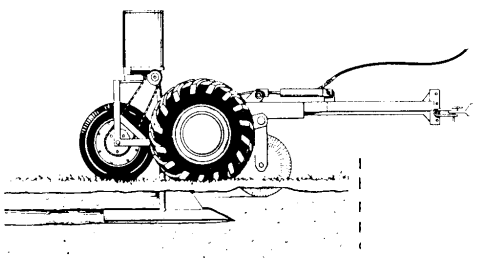


Fig. 9. A tractor-drawn mechanical bu
builder machine can be used to control pocket gophers. It automatically dispenses toxic bait into the artificial burrow it creates.

Table 1. Burrow builder machine bait application rate chart.

When bait-metering device is adjusted to deliver:	Spacing between rows of artificial burrows (feet)													
	10	12	14	16	18	20	22	24	26	28	30	32	34	36
Pounds/1,000 feet of burrow	Pounds of bait delivered per acre													
0.1	0.44	0.36	0.31	0.27	0.24	0.22	0.20	0.18	0.17	0.16	0.15	0.14	0.13	0.12
0.2	0.87	0.73	0.62	0.54	0.48	0.44	0.40	0.36	0.34	0.31	0.29	0.27	0.26	0.24
0.3	1.30	1.10	0.93	0.82	0.73	0.65	0.59	0.54	0.50	0.47	0.44	0.41	0.38	0.36
0.4	1.70	1.50	1.20	1.10	0.97	0.87	0.79	0.73	0.67	0.62	0.58	0.54	0.51	0.48
0.5	2.20	1.80	1.60	1.40	1.20	1.10	0.99	0.91	0.84	0.78	0.73	0.68	0.64	0.61
0.6	2.60	2.20	1.90	1.60	1.50	1.30	1.20	1.10	1.00	0.93	0.87	0.82	0.77	0.73
0.7	3.00	2.50	2.20	1.90	1.70	1.50	1.40	1.30	1.20	1.10	1.00	0.95	0.90	0.85
0.8	3.50	2.90	2.50	2.20	1.90	1.70	1.60	1.50	1.30	1.20	1.20	1.10	1.00	0.97
0.9	3.90	3.30	2.80	2.50	2.20	2.00	1.80	1.60	1.50	1.40	1.30	1.20	1.20	1.10
1.0	4.40	3.60	3.10	2.70	2.40	2.20	2.00	1.80	1.70	1.60	1.50	1.40	1.30	1.20
1.1	4.80	4.00	3.40	3.00	2.70	2.40	2.20	2.00	1.80	1.70	1.60	1.50	1.40	1.30
1.2	5.20	4.40	3.70	3.30	2.90	2.60	2.40	2.20	2.00	1.90	1.70	1.60	1.50	1.50
1.3	5.70	4.70	4.00	3.50	3.10	2.80	2.60	2.40	2.20	2.00	1.90	1.80	1.70	1.60
1.4	6.10	5.10	4.40	3.80	3.40	3.00	2.80	2.50	2.30	2.20	2.00	1.90	1.80	1.70
1.5	6.50	5.40	4.70	4.10	3.60	3.30	3.00	2.70	2.50	2.30	2.20	2.00	1.90	1.80
1.6	7.00	5.80	5.00	4.40	3.90	3.50	3.20	2.90	2.70	2.50	2.30	2.20	2.00	1.90
1.7	7.40	6.20	5.30	4.60	4.10	3.70	3.40	3.10	2.80	2.60	2.50	2.30	2.20	2.10
1.8	7.80	6.50	5.60	4.90	4.40	3.90	3.60	3.30	3.00	2.80	2.60	2.40	2.30	2.20
1.9	8.30	6.90	5.90	5.20	4.60	4.10	3.80	3.40	3.20	3.00	2.80	2.60	2.40	2.30
2.0	8.70	7.30	6.20	5.40	4.80	4.40	4.00	3.60	3.40	3.10	2.90	2.70	2.60	2.40
2.1	9.10	7.60	6.50	5.70	5.10	4.60	4.20	3.80	3.50	3.30	3.00	2.90	2.70	2.50
2.2	9.60	8.00	6.80	6.00	5.30	4.80	4.40	4.00	3.70	3.40	3.20	3.00	2.80	2.70
2.3	10.00	8.30	7.20	6.30	5.60	5.00	4.60	4.20	3.90	3.60	3.30	3.10	2.90	2.80
2.4	10.50	8.70	7.50	6.50	5.80	5.20	4.80	4.40	4.00	3.70	3.50	3.30	3.10	2.90
2.5	10.90	9.10	7.80	6.80	6.10	5.40	5.00	4.50	4.20	3.90	3.60	3.40	3.20	3.00
2.6	11.30	9.40	8.10	7.10	6.30	5.70	5.10	4.70	4.40	4.00	3.80	3.50	3.30	3.10
2.7	11.80	9.80	8.40	7.40	6.50	5.90	5.30	4.90	4.50	4.20	3.90	3.70	3.50	3.30
2.8	12.20	10.20	8.70	7.60	6.80	6.10	5.50	5.10	4.70	4.40	4.10	3.80	3.60	3.40
2.9	12.60	10.50	9.00	7.90	7.00	6.30	5.70	5.30	4.90	4.50	4.20	3.90	3.70	3.50
3.0	13.10	10.90	9.30	9.20	7.30	6.50	5.90	5.40	5.00	4.70	4.40	4.10	3.80	3.60

EXAMPLE: To determine the amount of bait that will be delivered if a mechanical baiter is set to apply 0.5 pound per 1,000 feet of burrow, and is to be used between orchard rows with 22-foot spacings, read down row spacing column 22 until opposite the designated 0.5 pound. The answer (to the nearest hundredth) is 0.99 pound.

Fumigants

Federally registered fumigants include aluminum phosphide and gas cartridges with various active ingredients. These fumigants usually are not very successful in treating pocket gophers because the gas moves too slowly through the tunnel system. Unless the soil is moist, the fumigant will diffuse through the soil out of the gopher's tunnel.

Carbon monoxide from automobile exhaust is more effective than other fumigants because of its greater volume and pressure. Connect a piece of hose or pipe to the engine exhaust, and place it in a tunnel near a fresh soil mound. Pack soil around the hose or pipe and allow the engine to run for about 3 minutes. The method is usually 90% effective. The engines of newer vehicles with antipollution devices require a longer running time since they do not produce as much carbon monoxide. This procedure requires no registration.

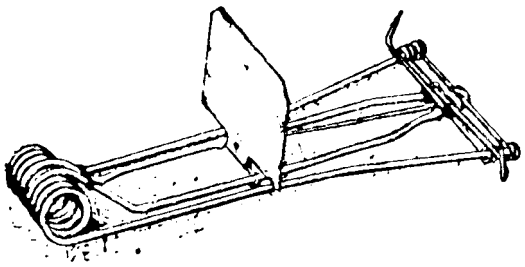
Trapping

Trapping is extremely effective for pocket gopher control in small areas and for removal of remaining animals after a poisoning control program. Some representative traps are illustrated on the following page (Fig. 10) with instructions for setting them (Figs. 11 and 12).

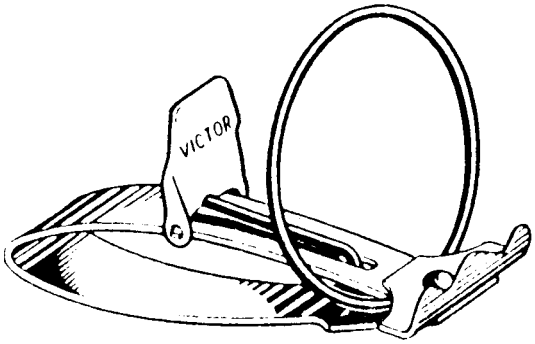
Vulnerability to trapping differs among species of pocket gophers and sometimes within the same species in different areas and at different times of the year.

For effective trapping, the first requisite is to find the tunnel. The procedure will vary depending on whether

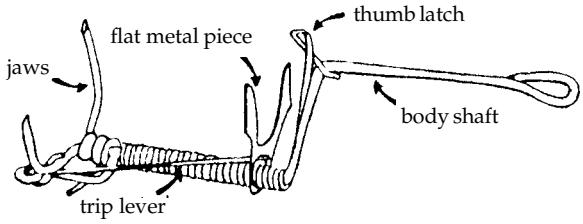
Fig. 10. Common types of traps for pocket gophers.



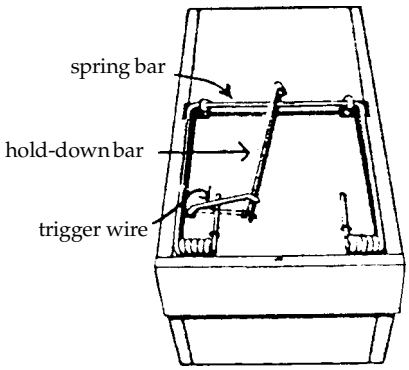
(a) Macabee® gopher trap



(b) Victor® Gopher Getter

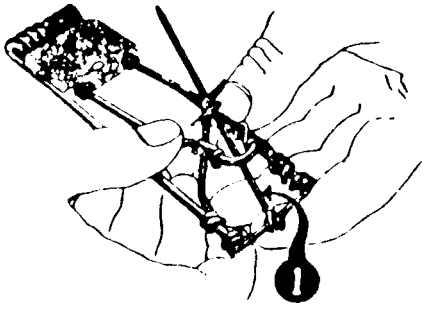


(c) Death-Klutch 1 gopher and mole trap

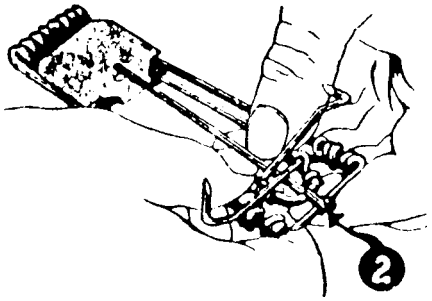


(d) Guardian (California box-type) gopher trap

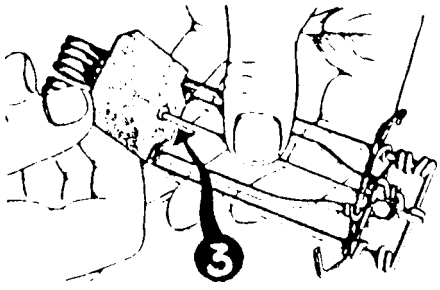
Fig. 11. Instructions for setting Macabee®.



Hold trap exactly as shown. Be sure left index finger holds trigger (1) in upright position.



Press thumbs down, and with left index finger guide hook on trigger (2) over end of frame of trap.



Still holding frame down, place other end of trigger (3) into small hole in plate.

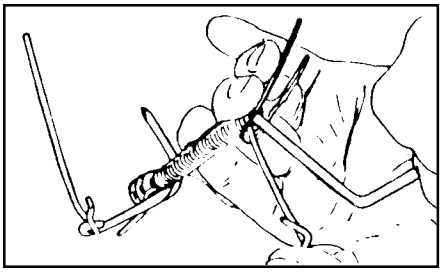
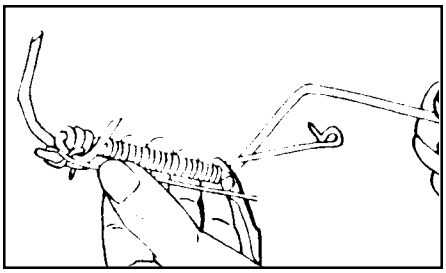
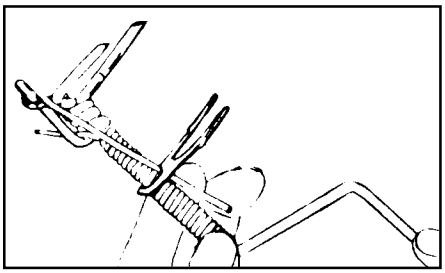


Fig. 12. Instructions for setting the Death-Klutch 1 gopher trap.

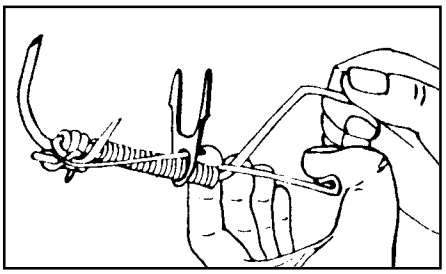
Pull thumb latch away from body shaft counter-clockwise (putting tension on spring), releasing from shipping position. Twist thumb clockwise until thumb latch stops.



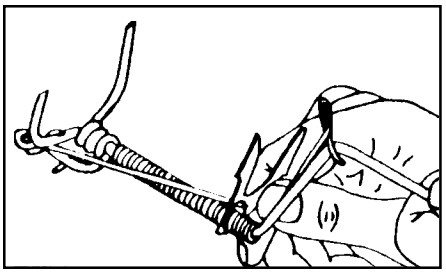
With jaws in open position (as shown), hook crooked end of trip lever over top of left jaw with long end under jaw. Push top of trip lever toward spring.



Slide flat metal piece toward jaws with points up. Put trip lever through large hole and move flat metal piece up about 1 inch.



To apply spring tension, hold body shaft in right hand, catch thumb latch with left fore and middle fingers under spring. Hold firm and crank body shaft clockwise one turn, and hook thumb latch back to body shaft. Caution: wear gloves as finger may touch end of trip lever. If this becomes a problem, trim tail of trip lever slightly.



Move flat metal piece to ear (away from jaws) near tip end of trip lever. Trap is now ready to place into burrow.

traps are set in the main tunnel or in the lateral tunnels (Fig. 13). To locate traps in the main tunnel, refer to the section on hand baiting. To locate the lateral tunnels, find a fresh mound and with a trowel or shovel, dig several inches away from the mound on the plug side. The lateral may be plugged with soil for several inches (cm) or several feet (m). However, fresh mounds are usually plugged only a few inches.

You may have to experiment with trap type and placement. Some trappers have success leaving tunnels completely open when they set their traps; others, when they place traps in the main, close off the tunnel completely, and when trapping the lateral, close most of the tunnel with sod. Traps can be marked above ground with engineering flags and should be anchored with a stake and wire or chain so a predator does not carry off the catch and the trap.

Trapping can be done year-round because gophers are always active, but a formidable effort is required for trapping when the soil is frozen. Trapping is most effective when gophers are pushing up new mounds, generally in spring and fall. If a trap is not visited within 48 hours, move it to a new location. Leave traps set in a tunnel system even if you have trapped a gopher in spring and early summer, when gophers are most likely to share their quarters.

Shooting

Since pocket gophers spend essentially all their time below ground, this method is impractical.

Other Methods

Buried utility cables and irrigation lines can be protected by enclosing them in various materials, as long as the outside diameter exceeds 2.9 inches (7.4 cm). Gophers can open their mouths only wide enough to allow about a 1-inch (2.5-cm) span between the upper and lower incisors. Thus, the recommended diameter presents an essentially flat surface to most pocket gophers. Cables can be protected in this manner whether they are armored or not. Soft metals such as lead and aluminum used for armoring cables are readily damaged by pocket gophers if the diameters are less than the suggested sizes.

Buried cables may be protected from gopher damage by surrounding the cable with 6 to 8 inches (15 to 20 cm) of coarse gravel. Pocket gophers usually burrow around gravel 1 inch (2.5 cm) in diameter, whereas smaller pebbles may be pushed to the surface.

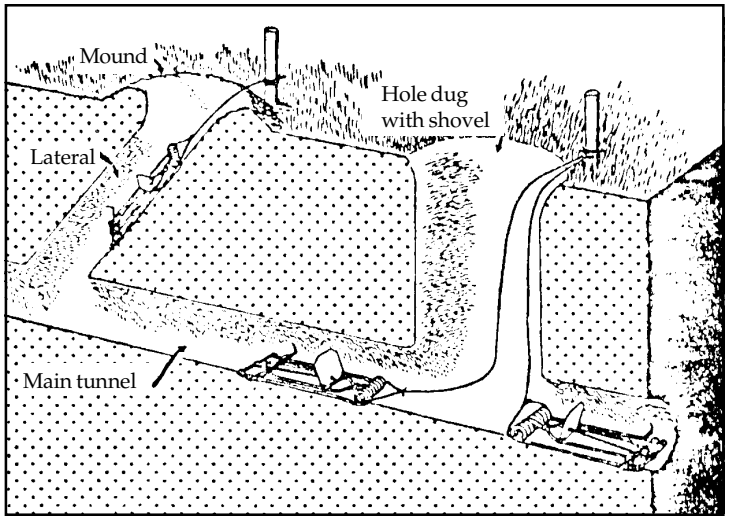


Fig. 13. Trap placement in lateral or main pocket gopher tunnels. Note that traps are staked.

Economics of Damage and Control

It is relatively easy to determine the value of the forage lost to pocket gophers. Botta's pocket gophers at a density of 32 per acre (79/ha) decreased the forage yield by 25% on foothill rangelands in California, where the plants were nearly all annuals. Plains pocket gophers reduced forage yield on rangelands in western Nebraska by 21% to 49% on different range sites. Alfalfa yields in eastern Nebraska were reduced as much as 46% in dryland and 35% in irrigated alfalfa. Losses of 30% have been reported for hay meadows.

Calculating the cost of control operations is only slightly more complicated. However, the benefit-cost analysis of control is still not straightforward. More research data are needed on managing the recovery of forage productivity. For example, should range be fertilized, rested, or lightly grazed? Should gopher mounds on alfalfa be lightly harrowed? A study of northern pocket gopher control on range production in southern Alberta indicated that forage yields increased 16%, 3 months after treatment. The potential for complete yield recovery the first year following gopher removal has been noted for a fibrous-rooted variety of alfalfa.

Economic assessment should also be made to determine the cost of no control, the speed of pocket gopher infestation, and the costs associated with dulled or plugged mowing machinery or mechanical breakdowns caused by the mounds. Assessment could also be made for damages to buried cable, irrigation structures, trees, and so on.

The benefits of pocket gophers also complicate the economic analysis. Some of these benefits are: (1) increased soil fertility by adding organic matter such as buried vegetation and fecal wastes; (2) increased soil aeration and decreased soil compaction; (3) increased water infiltration and thus decreased runoff; and (4) increased rate of soil formation by bringing subsoil material to the surface of the ground, subjecting it to weathering.

Decisions on whether or not to control gophers may be influenced by the animals' benefits, which are long-term and not always readily recognized, and the damage they cause, which is obvious and sometimes substantial in the short-term. Landowners who are currently troubled by pocket gophers can gain tremendously by studying the gophers' basic biology. They would gain economically by learning how to manage their systems with pocket gophers in mind, and aesthetically by understanding how this interesting animal "makes a living."

The distribution of gophers makes it unlikely that control measures will threaten them with extinction. Local eradication may be desirable and cost-effective in some small areas with high-value items. On the other hand, it may be effective to simply reduce a population. There are also times when control is not cost-effective and therefore inadvisable. Complete control may upset the long-term integrity of ecosystems in a manner that we cannot possibly predict from our current knowledge of the structure and function of those systems.

Acknowledgments

We thank the many researchers and managers who have spent untold time studying these extremely interesting rodents. Some are listed in the reference section. Special thanks are due to Scott Hygnstrom for his editorial assistance; to Rex E. Marsh, Bob Timm, and Jan Hygnstrom for their helpful comments on an earlier draft, and to Diane Gronewold and Diana Smith for their technical assistance.

Figures 1, 2, and 6 from Schwartz and Schwartz (1981).

Figures 3 and 5 from Turner et al. (1973).

Figures 4a, 4b, and 4c after Hegdal and Harbour (1991), adapted by Bruce Jasch and Dave Thornhill.

Figures 7, 8, and 10 by Jill Sack Johnson.

Figure 9 courtesy of Elston Equipment Company.

Figure 11 courtesy of Z. A. Macabee Gopher Trap Company.

Figure 12 courtesy of P-W Manufacturing Company.

Figure 13 adapted from E. K. Boggess (1980), "Pocket Gophers," in *Handbook on Prevention and Control of Wildlife Damage*, Kansas State University, Manhattan.

Table 1 taken from Marsh and Cummings (1977).

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Robert M. Timm
Superintendent and Extension
Wildlife Specialist
Hopland Research & Extension Center
University of California
Hopland, California 95449

HOUSE MICE

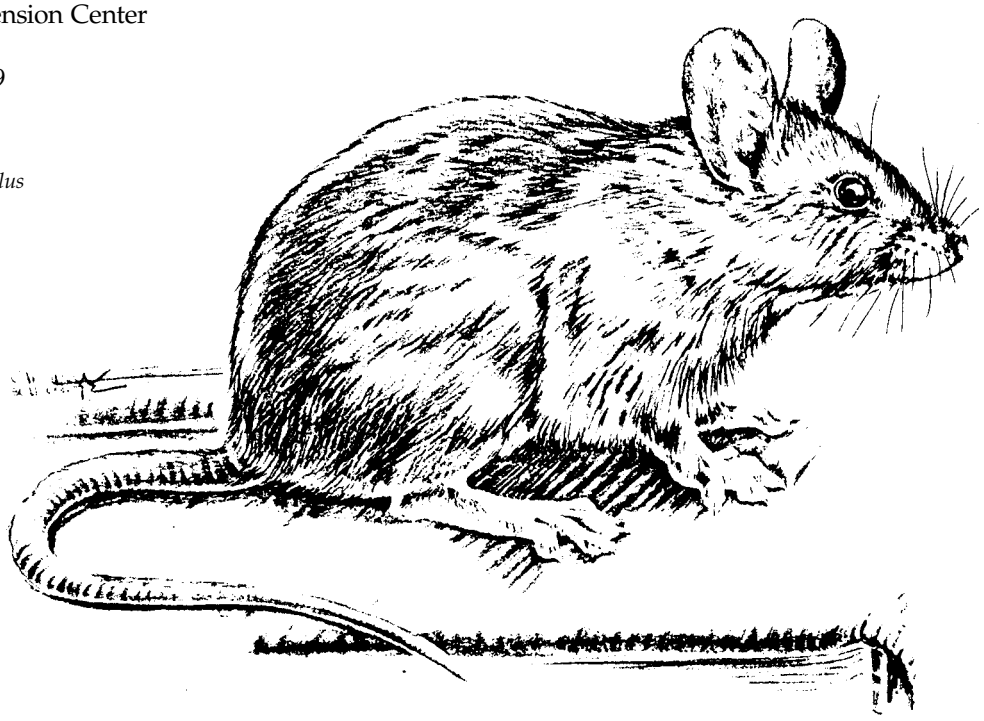


Fig. 1. House mouse, *Mus musculus*

Damage Prevention and Control Methods

Exclusion

Seal all openings larger than 1/4 inch (0.6 cm) wide.

Habitat Modification

Good sanitation practices reduce sources of food, water, and shelter.

Store foodstuffs in rodent-proof structures or containers.

Control weeds and remove debris from around structures.

Frightening

Ultrasonic devices have not been proven to control mice.

Repellents

Ro-pel®

Moth flakes (naphthalene) not specifically registered, but may be of some value.

Toxicants

Anticoagulant rodenticides (slow-acting chronic-type toxicants).
Brodifacoum (Talon®).
Bromadiolone (Maki®, Contrac®).
Chlorophacinone (RoZol®).
Diphacinone (Ditrac®).
Pindone (Pival®, Pivalyn®).
Warfarin (Final® and others).

Toxicants other than anticoagulants (may be acute or chronic poisons).
Bromethalin (Assault®, Vengeance®).
Cholecalciferol (Quintox®).
Zinc phosphide (Ridall Zinc®, ZP®).

Fumigants

Practical use is limited to structures, containers, and commodities; for use only by trained personnel.

Trapping

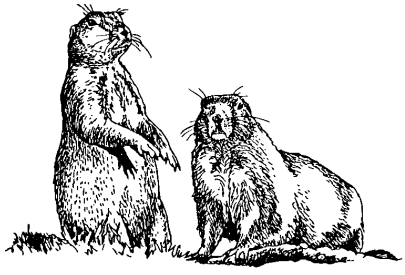
Snap traps.

Live traps (Sherman-type, Ketch-All®, Tin Cat®, and others).

Glue boards.

Other Methods

Predators: dogs and cats are of limited value in some situations.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

Identification

The house mouse (*Mus musculus*, Fig. 1) is a small, slender rodent that has a slightly pointed nose; small, black, somewhat protruding eyes; large, sparsely haired ears; and a nearly hairless tail with obvious scale rings. House mice are considered among the most troublesome and economically important rodents in the United States.

Adult house mice weigh about 2/5 to 4/5 ounce (11 to 22 grams). They are generally grayish brown with a gray or buff belly. Similar mice include the white-footed mice and jumping mice (which have a white belly), and harvest mice (which have grooved upper incisor teeth). For more details on species identification, see a field guide such as that by Burt and Grossenheider (1976).

Native to central Asia, this species arrived in North America with settlers from Europe and from other points of origin. A very adaptable species, the house mouse often lives in close association with humans and therefore is termed one of the "commensal" rodents along with Norway and roof rats. House mice are much more common in residences and commercial structures than are rats. Brooks (1973) regards them to be the most common mammal in cities, next to humans.

Range

Following their arrival on colonists' ships, house mice spread across North America and are now found in every state, including coastal areas of Alaska, and in the southern parts of Canada.

Habitat

House mice live in and around homes, farms, commercial establishments, and in open fields and agricultural lands. At times they may be found living far from human settlements, particularly where climates are moderate. The onset of cold weather each fall in temperate regions may cause mice to move into structures in search of shelter and food.

Food Habits

House mice eat many types of food but prefer seeds and grain. They are not hesitant to eat new foods and are considered "nibblers," sampling many kinds of items that may exist in their environment. Foods high in fat, protein, or sugar may be preferred even when grain and seed are present. Such items include bacon, chocolate candies, butter, and nutmeats.

Unlike Norway and roof rats, house mice can survive with little or no free water, although they readily drink water when it is available. They obtain their water from the food they eat. An absence of liquid water or food of adequate moisture content in their environment may reduce their breeding potential.

General Biology, Reproduction, and Behavior

House mice are mainly nocturnal, although at some locations considerable daytime activity may be seen. Seeing mice during daylight hours does not necessarily mean that a high population is present, although this is usually true for rats.

Mice have poor eyesight, relying on their hearing and their excellent senses of smell, taste, and touch. They are considered color-blind; therefore, for safety reasons, baits can be dyed distinctive colors without causing avoidance by mice, as long as the dye does not have an objectionable taste or odor.

House mice may burrow into the ground in fields or around structures when other shelter is not readily available. Nesting may occur in the ground or in any sheltered location. Nests are constructed of shredded fibrous materials such as paper, burlap, or other similar items, and generally have the appearance of a "ball" of material loosely woven together. They are usually 4 to 6 inches (10.2 to 15.2 cm) in diameter.

Litters of 5 or 6 young are born 19 to 21 days after mating, although females that conceive while still nursing may have a slightly longer gestation period. Mice are born hairless and with their eyes closed. They grow rapidly, and after 2 weeks they are covered with hair and their eyes and ears are open. They begin to make short excursions from the nest and eat solid food at 3 weeks. Weaning soon follows, and mice are sexually mature at 6 to 10 weeks of age.

Mice may breed year-round, but when living outdoors, they breed mostly in spring and fall. A female may have 5 to 10 litters per year. Mouse populations can therefore grow rapidly under good conditions, although breeding and survival of young decline markedly when population densities become high.

House mice have physical capabilities that enable them to gain entry to structures by gnawing, climbing, jumping, and swimming. For more detailed information on their physical abilities and the resulting need to design rodent-proof structures, see the chapter **Rodent-Proof Construction and Exclusion Methods.**

Studies indicate that during its daily activities, a mouse normally travels an area averaging 10 to 30 feet (3 m to 9 m) in diameter. Mice seldom travel farther than this to obtain food or water. Because of their limited movement and feeding behavior, both of which differ from those of commensal rats, they are much more difficult to control in some situations.

Mice constantly explore and learn about their environment, memorizing the locations of pathways, obstacles, food and water, shelter, and other elements in their domain. They quickly detect new objects in their environment but, unlike rats, do not fear them. Thus, they will almost immediately enter bait stations and sample new foods (baits). The degree to which mice consume a particular food

depends on the flavor of the food in addition to its physiological effect. Mice may reject baits simply because they do not taste as good as other available foods.

If the bait contains poison or some other substance that produces an ill effect (but not death) within a few hours, the bait will often become associated with the illness. Bait shyness can persist for weeks or months and may be transferred to nontoxic foods of similar types. Prebaiting, that is, training mice to feed repeatedly on nontoxic bait for a period of days prior to applying the toxicant in the bait, will largely prevent sublethal doses and thus bait shyness. It will also reduce the number of mice left to be bait shy. Prebaiting is especially recommended with zinc phosphide baits. All of the other toxic baits currently registered for house mice are chronic or slow-acting. Because of this slow action, the mice's subsequent illness is not associated with the bait even if a sublethal dose is consumed; thus, bait shyness does not usually occur. These baits, in effect, serve as their own prebait.

Damage and Damage Identification

When house mice live in or around structures, they almost always cause some degree of economic damage. In homes and commercial buildings, they may feed on various stored food items or pet foods. In addition, they usually contaminate foodstuffs with their urine, droppings, and hair. On farms, they may cause damage to feed storage structures and feed transporting equipment. A single mouse eats only about 3 grams of food per day (8 pounds [3.6 kg] per year) but destroys considerably more food than it consumes because of its habit of nibbling on many foods and discarding partially eaten items.

House mice living in fields may dig up and feed on newly planted grain, or may cause some damage to crops before harvest. But losses in stored foods are considerably greater. Mice commonly damage containers and packaging materials in warehouses where food and feeds are stored. Much of this loss is due to contamination with droppings and urine, making food unfit for human consumption.

House mice cause structural damage to buildings by their gnawing and nest-building activities. In livestock confinement facilities and similar structures, they may quickly cause extensive damage to insulation inside walls and attics. Such damage also occurs in homes, apartments, offices, and commercial buildings but usually at a slower rate because mouse populations in such structures are smaller. House mice often make homes in large electrical appliances, and here they may chew up wiring as well as insulation, resulting in short circuits which create fire hazards or other malfunctions that are expensive to repair. Mice may also damage stored items in attics, basements, garages, or museums. Damaged family heirlooms, paintings, books, documents, and other such items may be impossible to replace.

Among the diseases mice or their parasites may transmit to humans are salmonellosis (food poisoning), rickettsialpox, and lymphocytic choriomeningitis. Mice may also carry leptospirosis, ratbite fever, tapeworms, and organisms that can cause ringworm (a fungal skin disease) in humans. They have also been found to act as reservoirs or transmitters of diseases of veterinary importance, such as swine dysentery, a serious bacterial disease of swine often called "bloody scours."

Mouse Sign

The presence of house mice can be determined by a number of signs described below:

Droppings may be found along runways, in feeding areas, and near shelter. Differentiating between mouse droppings and those of certain insects may be difficult. Mouse droppings are about 1/4 inch (0.6 cm) long, whereas those of cockroaches are usually 1/8 to 1/4 inch (0.3 to 0.6 cm) long and under a magnifying glass show distinct longitudinal ridges and squared-off ends. In comparison, droppings of bats contain insect fragments and are more easily crushed between the fingers.

Tracks, including footprints or tail marks, may be seen on dusty surfaces or in mud (Fig. 2). A tracking patch made of flour, rolled smooth with a cylindrical object, can be placed in pathways overnight to determine if rodents are present.

Urine, both wet and dry, will fluoresce under ultraviolet light, although so will some other materials. Urine

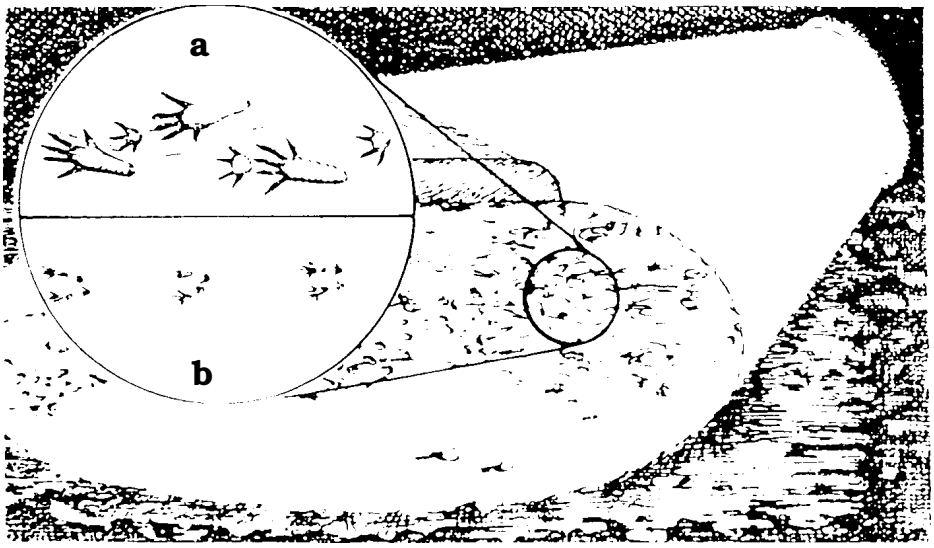


Fig. 2. Tracks left in dust by (a) Norway rat and (b) house mouse.

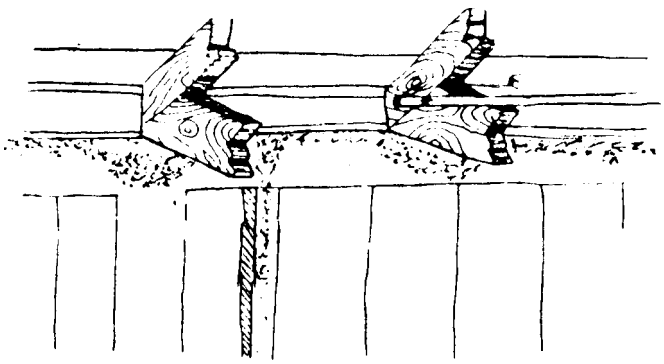


Fig. 3. Rub marks along beams, rafters, or other travel routes give evidence of rodent activity. Mouse rub marks can be distinguished from those of rats by their smaller size.

stains may occur along travelways or in feeding areas.

Smudge marks (rub marks) may occur on beams, rafters, pipes, walls, and other parts of structures. They are the result of oil and dirt rubbing off mice's fur along frequently traveled routes (Fig. 3). They may be less apparent than rub marks left by rats.

Gnawing may be visible on doors, ledges, in corners, in wall material, on stored materials, or on other surfaces wherever mice are present. Fresh accumulations of wood shavings, insulation, and other gnawed material indicate active infestations. Size of entry holes (often 1 1/2 inches [3.8 cm] in diameter or less for mice, 2 inches [5 cm] or larger for rat) or tooth marks can be used to distinguish rat gnawing from mouse gnawing. Mice keep their paired incisor teeth, which grow continuously, worn down by gnawing on hard surfaces and by working them against each other.

Sounds such as gnawing, climbing in walls, running across the upper surface of ceilings, and squeaks are common where mice are present.

Visual sightings of mice may be possible during daylight hours, and mice also can be seen after dark with the aid of a flashlight or spotlight.

Nests frequently are found when cleaning garages, closets, attics, basements, and outbuildings where mice are present. They consist of fine, shredded fibrous materials.

Odors may indicate the presence of house mice. A characteristic musky odor is a positive indication that house mice are present, and this odor can be used to differentiate their presence from that of rats.

Estimating Mouse Numbers

Mouse sign and visual sightings are of limited value in accurately estimating mouse numbers, but they are the simplest and often the only practical method available. Search premises thoroughly when looking for mice. In structures, searches should include attics, basements, around foundations, crawl spaces, and behind and under stored materials.

One method to detect the presence of mice is to make nontoxic tracking-dust patches of flour or talc at 20- to 30-foot (6- to 9-m) intervals throughout a structure. The number of patches showing tracks after 24 hours, and the abundance of tracks in each patch, indicate the size of the population. Because house mice, unlike rats, do not travel far from their nests or shelter, the percentage of patches showing tracks is a good indicator of the relative size and distribution of the mouse population.

Snap trapping is also an excellent way to determine the presence of mice. A relative index of mouse abundance can be calculated from the number of mice trapped for a certain number of traps set during 1 or more nights (for example, 35 mice caught per 100 trap nights).

Legal Status

House mice are not protected by law. They may be controlled using any pesticide registered by federal or state authorities for this purpose, or they may be controlled by use of mechanical methods such as traps.

Damage Prevention and Control Methods

Effective prevention and control of house mouse damage involves three aspects: rodent-proof construction, sanitation, and population reduction by means of traps, toxicants, or fumigants. The first two are useful as preventive measures, but when a house mouse infestation already exists, some form of population reduction is almost always necessary. A flow chart outlining steps in controlling house mice is found in figure 4.

Control of house mice differs in important ways from the control of Norway or roof rats. Mice are smaller and therefore can enter narrower openings, making rodent-proofing more difficult. They have limited areas of movement (home range) and require little or no free water. While having a reproductive capability that is higher than that of rats, house mice are usually less sensitive (often far less sensitive) to many rodenticides. Persons who do not take these differences into account when attempting house mouse control may expect poor results.

After rats are controlled at a given location, house mice may increase in numbers by moving in from elsewhere or by reproduction. This may be expected because habitats suitable for rats are usually even more suitable for mice. One should anticipate that following rat control, the potential for house mouse problems may increase, and control measures should be taken before mouse numbers reach high levels.

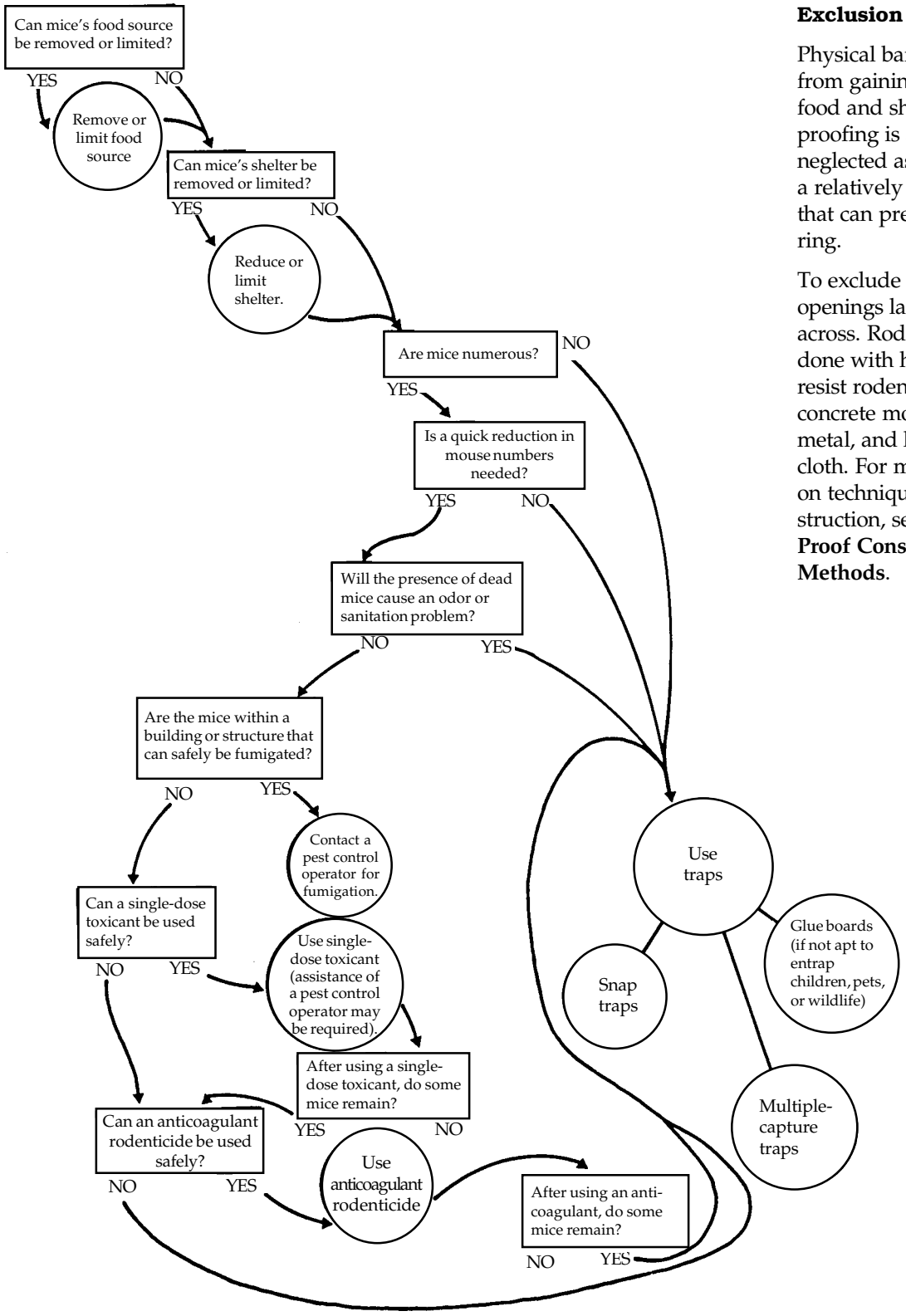


Fig. 4. A flow chart of steps in controlling house mouse populations. Additional factors, such as the cost of particular control methods, must be taken into account when planning a control program (see text).

Exclusion

Physical barriers can prevent mice from gaining entry to structures where food and shelter are available. Rodent-proofing is an important and often neglected aspect of rodent control. It is a relatively permanent form of control that can prevent damage from occurring.

To exclude mice, seal all holes and openings larger than 1/4 inch (0.6 cm) across. Rodent-proofing should be done with heavy materials that will resist rodent gnawing. These include concrete mortar, galvanized sheet metal, and heavy-gauge hardware cloth. For more detailed information on techniques of mouse-proof construction, see the chapter **Rodent-Proof Construction and Exclusion Methods**.

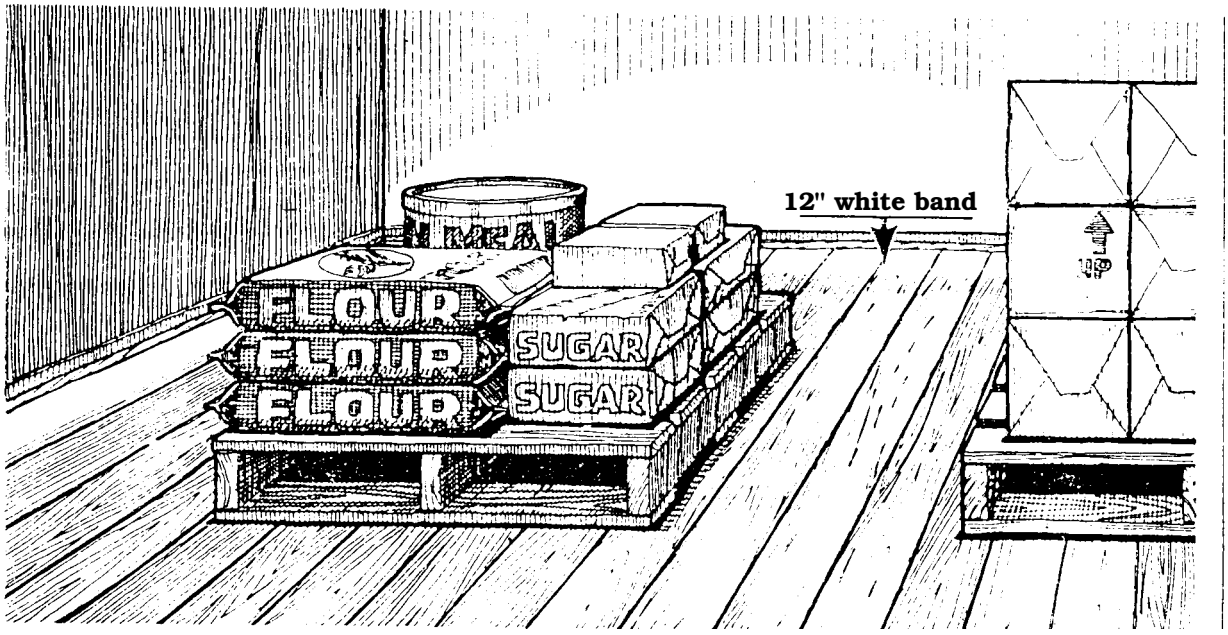


Fig. 5. A 12-inch (30.5-cm) white painted band makes inspection for rodent sign easier and reminds personnel not to store commodities too close to walls.

Habitat Modification

Sanitation, which includes good housekeeping practices and proper storage and handling of food materials, feed, and garbage, is often stressed as a method of rodent control. Unfortunately, even the best sanitation will not eliminate house mice. It will, however, aid in control by permitting easier detection of mouse sign, increasing effectiveness of traps and baits by reducing competing food items, and by preventing mice from flourishing and reaching high populations.

Although house mice are less dependent upon humans for their existence than are Norway rats, they are much more adaptable to living with people. They require very little space and only small amounts of food. Mice have been known to inhabit buildings even before construction has been complete, living off the crumbs and scraps of worker's lunches. In offices, mice may live behind cabinets or furniture and feed on scraps or crumbs from lunches and snacks and on cookies or candy bars kept in desks. In homes, they may find ample food in kitchens, and in the garage they will eat sacked or spilled pet food, grass seed, or insects such as cockroaches. Thus, no matter how good the sanitation, most buildings in which food is stored, prepared, or consumed will support at least a few mice. For this reason, a constant watch must be kept for mice that may invade the premises.

Where possible, store bulk foods in rodent-proof containers or rooms. Stack sacked or boxed foods in orderly rows on pallets in a way that allows for thorough inspection for evidence of mice. In such storage areas, keep stored materials away from walls. A 12-inch (30.5-cm) white band painted on the floor next to the wall serves as a reminder to keep items away from walls. It also will allow you to detect rodent droppings or other sign more easily (Fig. 5). Sweep floors frequently to permit ready detection of fresh droppings.

When storing foods or feed on pallets, keep in mind that mice can jump up more than 12 inches (30.5 cm) from a flat surface. They are also good climbers and can walk up surfaces such as wood or concrete (unless the surfaces have a slick finish). Mice can live for considerable periods of time within a pallet of feed without coming down to the floor.

Regular removal of debris and control of weeds from around structures will reduce the amount of shelter available to rodents. In some instances, a strip of heavy gravel placed adjacent to building foundations or other structures will reduce rodent burrowing at these locations. In any event, keep the perimeter of buildings and other structures clean of weeds and debris (including stacked lumber, firewood, and other stored materials) to discourage rodent activity and to allow easier detection of rodent sign.

Frightening

Mice are somewhat wary animals and can be frightened by unfamiliar sounds or sounds coming from new locations. Most rodents, however, can quickly become accustomed to new sounds heard repeatedly.

For years, devices that produce ultrasonic sound that is claimed to control rodents have come and gone on the market. There is little evidence to suggest that rodents' responses to nonspecific, high-frequency sound is any different from their response to sound within the range of human hearing.

What is known about rodents and sound?

—Unusually loud, novel, or ultrasonic sounds, which rodents can hear, will frighten them and may cause temporary avoidance lasting from a few minutes to a few weeks.

What is known about ultrasonic sound?

—It is very directional and does not travel around corners well; thus, sound shadows or voids are created.

—Ultrasound does not travel very far. It loses its intensity rapidly as it leaves the source.

—Ultrasound has not been shown to drive established rodents out of buildings or areas, nor has it been proven to cause above-normal mortality in their populations. While it is possible to cause convulsions or permanent physiological damage to rodents with ultrasound, the intensity of such sounds must be so great that damage to humans or domestic animals would also be likely. Commercial ultrasonic pest control devices do not produce sound of such intensity.

Recent tests of commercial ultrasonic devices have indicated that rodents may be repelled from the immediate area of the ultrasound for a few days, but then will return and resume normal activities. Other tests have shown the degree of repellency to depend upon the particular ultrasonic frequencies used, their intensity, and the preexisting condition of the rodent infestation. Ultrasonic sound has very limited usefulness in rodent control. The advertising claims for many commercial devices are unsubstantiated by scientific research. Since commercial ultrasonic devices are often expensive and of questionable effectiveness, they cannot be recommended as a solution to rodent problems.

Repellents

Rodents find some types of tastes and odors objectionable, but chemical repellents are seldom a practical solution to mouse infestations. Substances such as moth balls (naphthalene) or household ammonia, in sufficient concentration, may have at least temporary effects in keeping mice out of certain enclosed areas. These are not specifically registered by the EPA as mouse repellents, however.

Ro-pel® is registered for use in repelling house mice and other rodents from gnawing on trees, poles, fences, shrubs, garbage, and other objects. Little information is currently available on its effectiveness against house mice.

Other solutions to rodent problems, including rodent-proof construction and methods of population reduction, are usually more permanent and cost-effective than the use of repellents.

Toxicants

Rodenticides were formerly classified into two groups, single-dose (acute) toxicants and multiple-dose (chronic) toxicants. However, the complexity in mode of action of newer rodenticides makes these classifications outdated. A classification into two groups, the first group including all anticoagulants and the second group all other compounds ("non-anticoagulants"), is currently more useful.

Anticoagulants (slow-acting, chronic toxicants). House mice are susceptible to all of the various anticoagulant rodenticides (Table 1), but they are generally less sensitive (often far less sensitive) to the active ingredients than are Norway or roof rats. It usually requires a few more feedings to produce death with the first-generation anticoagulants (such as warfarin, diphacinone, and chlorophacinone) than with the second-generation anticoagulants (such as brodifacoum and bromadiolone). All anticoagulants provide good to excellent house mouse control when prepared in acceptable baits. A new second-generation anticoagulant, difethialone, is presently being developed and EPA registration is anticipated in the near future. The characteristics of the various anticoagulant rodenticides are described further under Anticoagulants in the **Pesticides** section, and in the chapter **Norway Rats**.

Table 1. Anticoagulants used for house mouse control in the United States.

Common name and typical trade names	Chemical name	Usual types of formulations			Percent active ingredient used in food bait
		Food bait	Liquid	Tracking powder	
Hydroxycoumarins					
Warfarin (Final® and others)	3-(α-acetonylbenzyl)-4-hydroxycoumarin	X	X		0.025
Brodifacoum (Talon®)*	3-[3(4'-bromo[1,1′biphenyl]-4-yl)-1,2,3,4-tetrahydro-1-naphthalenyl]-4-hydroxy-2H-1-benzopyran-2-one	X			0.005
Bromadiolone (Maki®, Contrac®)*	3-[3-(4'-bromo[1,1′biphenyl]-4-yl)-3-hydroxy-1-phenylpropyl]-4-hydroxy-2H-1-benzopyran-2-one	X			0.005
Difethialone*	[(bromo-4'-[biphenyl-1-1']-yl-4) 3-tetrahydro-1,2,3,4-napthyl-1] 3-hydroxy-4, 2H-1-benzo-thiopyran-2-one	X			0.0025
Indandiones					
Chlorophacinone (RoZol®)	2-[(*p*-chlorophenyl)phenylacetyl]-1,3-indandione	X		X	0.005
Diphacinone (Ditrac®)	2-diphenylacetyl-1,3-indandione	X		X	0.005
Pindone (Pival®, Pivalyn®)	2-pivalyl-1,3-indandione	X	X		0.025

* Second-generation anticoagulants especially useful for the control of warfarin-resistant rats and mice.

Because of their similarity in mode of action, all anticoagulant baits are used in a similar fashion. Label directions commonly instruct the user to "maintain a continuous supply of bait for 15 days or until feeding ceases," thus ensuring that the entire mouse population has ample opportunity to ingest a lethal dose of the bait. Anticoagulants have the same effect on nearly all warm-blooded animals, but the sensitivity to these toxicants varies among species. If misused, anticoagulant rodenticides can be lethal to nontarget animals such as dogs, pigs, and cats. Additionally, residues of anticoagulants which are present in the bodies of dead or dying rodents can cause toxic effects to scavengers and predators. In general, however, the secondary poisoning hazard from anticoagulants is relatively low.

Brodifacoum and bromadiolone baits, because of their potential to be lethal in a single feeding, can be more effective than the other anticoagulants in certain situations. Chlorophacinone (RoZol®) and diphacinone (Ditrac®) are similar to each other in potency and are more toxic than the anticoagulant compounds developed earlier. Thus, they are formulated at lower concentrations. Chlorophacinone and diphacinone may kill some mice in a single feeding, but multiple feedings are needed to give adequate control of a mouse population.

Pindone (Pival®, Pivalyn®) is also less potent than chlorophacinone or diphacinone, and is similar to warfarin in effectiveness against house mice. It has some properties that resist insects and growth of mold in prepared baits.

Warfarin (Final® and other trade names) was the first marketed anticoagulant and is, therefore, the best known and most widely used. It is effective against house mice, although some warfarin contains small quantities of contaminants that apparently can reduce bait acceptance. This has been resolved with the development of encapsulated warfarin.

Anticoagulant Resistance. Within any population of house mice, some individuals are less sensitive to anticoagulants than others. Where anticoagulants have been used over long periods of time at a particular location, there is an increased potential for the existence of a population that is somewhat resistant to the lethal effects of the baits. Such resistant populations of house mice have been identified at a number of locations throughout the United States. Although not common, resistance may be underestimated because relatively few resistance studies have been conducted on house mice. Nevertheless, resistance is of little consequence in the control of house mice with the newer rodenticides available. When anticoagulant resistance to the first-generation anticoagulants is known or suspected, use of these compounds should be avoided in favor of the second-generation anticoagulants or one of the non-anticoagulant products.

Anticoagulant Bait Failure. Resistance is only one (and perhaps the least likely) reason for failure in the control of mice with anticoagulant baits. Control with baits that are highly accepted may fail for one or more of the following reasons:

— Too short a period of bait exposure.

— Insufficient bait and insufficient replenishment of bait (none remains from one baiting to the next).

— Too few bait stations and/or too far apart. For mice, stations should be within 6 feet (2 m) of one another in areas where mice are active.

— Too small a control area, permitting mice to move in from untreated adjacent areas.

— Genetic resistance to the anticoagulant. Although this is unlikely, it should be suspected if about the same amount of bait is taken daily for several weeks.

Reasons for failure to achieve control with anticoagulant baits that are poorly accepted:

— Poor bait choice, or bait formulated improperly. Other foods are more attractive to the mice.

— Improperly placed bait stations. Other foods are more convenient to the mice.

— Abundance of other food choices.

— Tainted bait: the bait has become moldy, rancid, insect-infested, or contaminated with other material that reduces acceptance. Discard old bait periodically, and replace it with fresh.

Occasionally, mice accept bait well and an initial population reduction is successful. Then bait acceptance appears to stop although some mice remain. In such instances, it is likely that the remaining mice never accepted the bait, either because of its formulation or placement. The best strategy is to switch to a different bait formulation, place baits at different locations, and/or use other control methods such as traps.

Other Rodenticides. The older rodenticides, formerly referred to as acute toxicants, such as arsenic trioxide, phosphorus, strychnine, and Compound 1080, are no longer registered for house mice. Newer rodenticides are much more effective and have resulted in the phasing out of these older materials over the last 20 years.

At present, three non-anticoagulant rodenticides (Table 2) are registered by EPA against house mice: bromethalin, cholecalciferol (vitamin D_3), and zinc phosphide. All are potentially useful for controlling anticoagulant-resistant populations of house mice.

Of these active ingredients, bromethalin and cholecalciferol are formulated to serve as chronic rodenticides, applied so that house mice will have the opportunity to feed on the baits one or more times over the period of one to several days. Bait acceptance is generally good when formulations appropriate for house mice are selected. Zinc phosphide differs from the other two compounds in that prebaiting (offering mice similar but nontoxic bait prior to applying the zinc phosphide-treated bait) is recommended to increase bait acceptance. Zinc phosphide baits are not designed to be left

Table 2. Other (non-anticoagulant) rodenticides used to control house mice in the United States.

Common Name	Chemical Name	Acute oral LD_{50} for mice, mg/kg	Time to death	Odor	Taste	Percent active ingredient in food bait	Relative hazard	Mode of Action
Bromethalin (Assault®, Vengeance®)	N-methyl-2,4-dinitro-N-(2,4,6-tribromophenyl)-6-(trifluoromethyl) benzenamine	5.25-8.13	2-4 days	None	Slight	0.01	Moderate	Central nervous system depression and paralysis
Cholecalciferol (vitamin D_3, Quintox®)	9,10-Seocholesta-5,7,10 (19)-trein-3 betaol	42.5	3-4 days	Slight	None	0.075	Low to moderate	Mobilizes calcium resulting in death from hypercalcemia
Zinc phosphide	Zinc phosphide	40	1/2-20 hours	Strong	Strong	1.0-2.0	Moderate	Phosphine gas enters circulatory system; heart paralysis, gastrointestinal and liver damage

available to mice for more than a few days, as continued exposure is likely to result in bait shyness within the population. Be sure to follow label recommendations on any specific product to achieve best success.

Bait Selection and Formulation

Oatmeal, ground or rolled wheat, rolled barley, ground or rolled milo, and corn have been successfully used as chief ingredients of toxic baits for house mice. Grass seed, such as whole canary grass seed (*Phalaris canarienses*), is often highly accepted by house mice and can be very effective as a principal bait ingredient. In general, the fresher the bait, the better it will be accepted by mice. Rodent baits should always be made from high-quality food materials, and baits should be replaced or replenished regularly.

Food preferences may vary among mouse populations and individuals. Bait materials similar to foods mice are accustomed to eating are often a good choice, particularly if their normal foods are limited or can be made less available to them. In past years, many people involved in house mouse control preferred to mix their own baits so as to tailor them to the food preference of a specific mouse population. Today, there is a wide selection of ready-to-use baits which are commercially available. It is still important, particularly in moderate- to large-scale mouse control programs, to check for differences in bait acceptance among candidate baits prior to investing time and money in a specific bait product. Place about 1/2 ounce (14 g) of each of several ready-to-use baits about 4 inches (10 cm) apart in several locations where mice are present. Check baits the next day to see which ones are preferred.

Ready-to-use baits come in a variety of formulations. Grain-based baits in a loose meal or pelleted form are available in bulk or packaged in small plastic, cellophane, or paper "place packs" (Fig. 6). These packets keep bait fresh and make it easy to place baits into burrows, walls, or other locations. Mice will gnaw into these bags to feed on an acceptable bait. Pelleted baits can more easily be carried by mice to other locations. Such hoarding of food by mice is not uncommon. It may result in amounts of bait being moved to places where it is undetected or difficult to recover and may, if accessible, be hazardous to nontarget species. On the other hand, pelleted bait avoids some problems common to loose baits — settling out of different-sized particles during shipment and uneven mixing of the toxicant. Pellets are easily manipulated by mice, increasing the attractiveness of this form of bait.

Anticoagulant baits have also been formulated into wax and extruded blocks (Fig. 7). These are particularly useful where moisture may cause loose grain

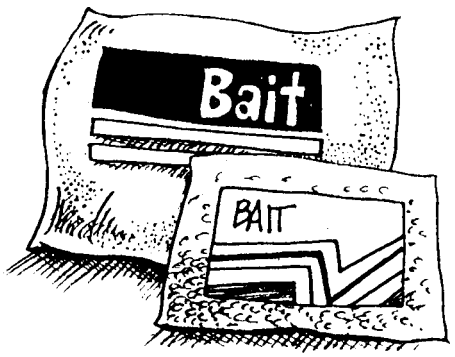


Fig. 6. Various types of place packs containing rodenticides are commercially available.

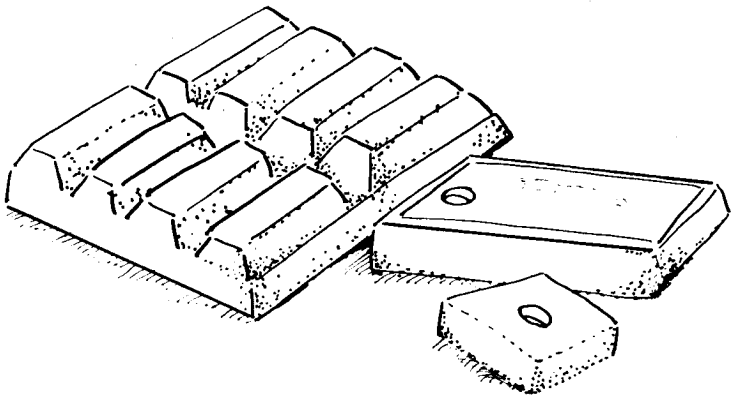


Fig. 7. Wax and extruded bait blocks are useful in damp locations where loose baits become spoiled quickly.

baits to spoil. Mice accept paraffin block baits less readily than loose or pelleted grain baits, but acceptance of extruded bait blocks is high.

Where no water is available, water or food items of high moisture content are often more readily accepted than dry baits. Sodium salts of anticoagulants are available as concentrates to be mixed with water, making a liquid bait (Fig. 8). Although mice require little or no water to survive, they will readily drink it when available. Water baits can be an effective supplement to other control measures where water is scarce. They are particularly useful in grain storage structures, warehouses, and other such locations. Rodents are more easily able to detect anticoagulants in water baits than in food baits; therefore, up to 5% sugar is sometimes added to liquid baits to increase rodents' acceptance of the bait solution. Since water is attractive to most animals, use water baits in ways that prevent nontarget animals from drinking them.

Bait Stations

Bait stations (bait boxes) may increase both the effectiveness and safety of rodenticides. They came into general use after the development of the first-generation anticoagulants, which require that a continuous supply of bait be made available to rodents. Bait stations are useful because they:

— protect bait from moisture and dust;

— provide a protected place for rodents to feed, allowing them to feel more secure. This is an important advantage when baiting mice, which apparently like to spend time feeding inside such bait boxes;

— keep other animals (pets, livestock, desirable wildlife) and children away from hazardous bait;

— allow placement of bait in locations where it would otherwise be difficult because of weather or potential hazards to nontarget animals;

— help prevent the accidental spilling of bait;

— allow easy inspection of bait to see if rodents are feeding on it.

Kinds of Bait Stations. Bait stations can contain solid baits (food baits), liquid baits, or both. Bait boxes can be purchased from commercial suppliers or made at home. Manufactured bait boxes made of plastic, cardboard, or metal are sold to pest control companies and to the public (Fig. 9) in sizes for rats or mice. Some farm supply and agricultural chemical supply stores have them in stock or can order them. Recent research suggests mice may prefer to feed in cardboard bait stations rather than plastic ones.

Bait boxes can be built from scrap materials, and homemade stations can be designed to fit individual needs. Make them out of sturdy materials so they cannot be easily knocked out of place

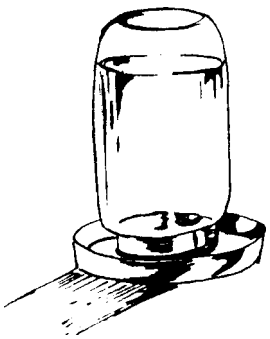


Fig. 8. Liquid baits can be placed in fonts or other similar containers.

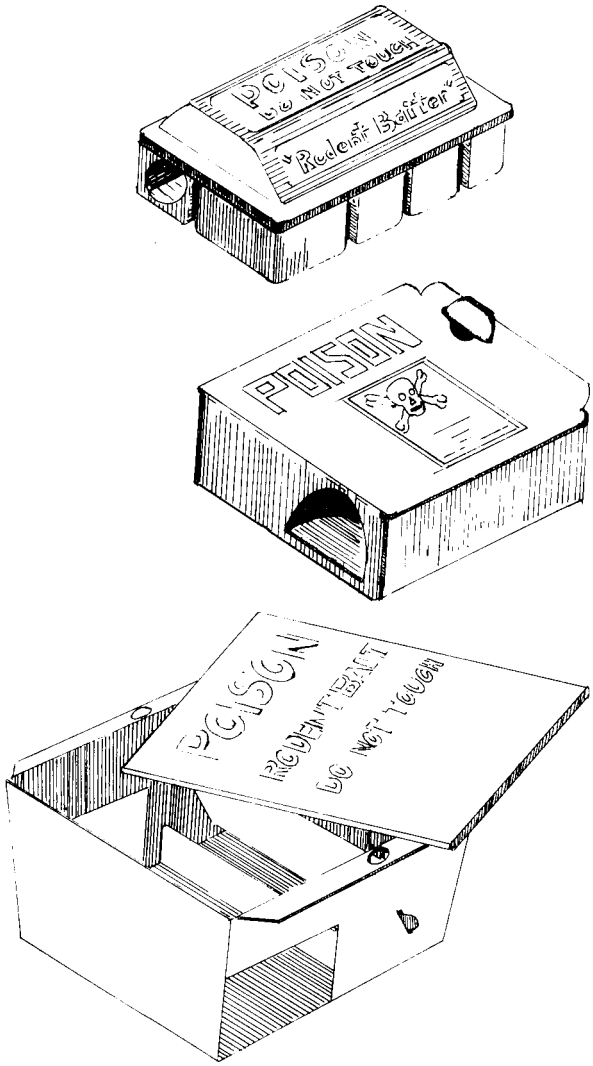


Fig. 9. Examples of commercially manufactured rodent bait stations.

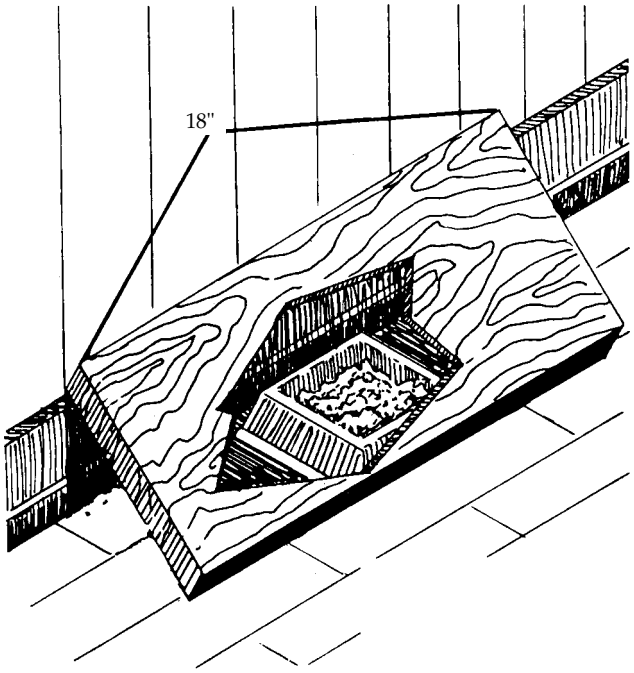


Fig. 10. A flat board nailed to a wall protects rodent bait from nontarget animals and allows rodents to feed in a sheltered location. The board should be at least 18 inches (45.7 cm) long to keep pets and children from reaching the bait.

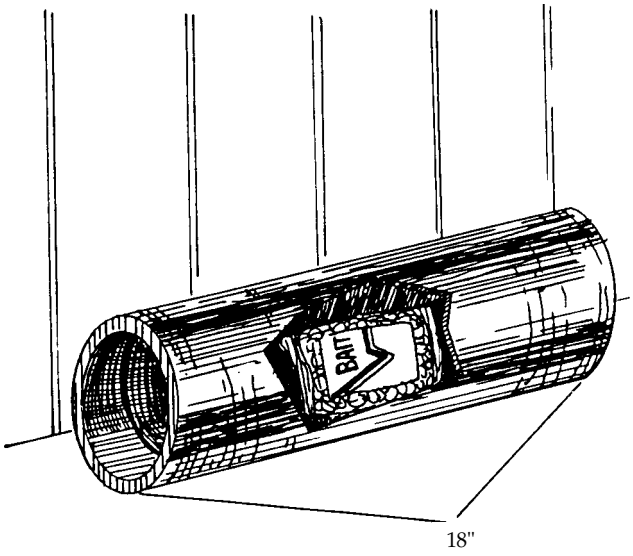


Fig. 11. Rodent bait station made from a length of pipe. Pipe diameter can be 2 to 3 inches (5.1 to 7.6 cm) for mice; 3 1/2 to 6 inches (8.9 to 15.2 cm) for rats.

or damaged. Where children, pets, or livestock are present, be careful to construct the stations so that the bait is accessible only to rodents. Locks, seals, or concealed latches are often used to make bait boxes more tamperproof. Clearly label all bait boxes or stations with "Poison" or "Rodent Bait — Do Not Touch," or with a similar warning. Some rodenticides or situations may require use of tamper-resistance bait stations. If so, use only bait boxes or stations which are so designated, and also be sure to secure them to buildings by nailing or gluing them to walls or floors in a way that will not permit a person or animal to knock them over or shake the bait out.

Bait Station Design. Bait stations should be large enough to allow several rodents to feed at once. They can be as simple as a flat board nailed at an angle to the bottom of a wall (Fig. 10), or a length of pipe into which bait can be placed (Fig. 11). More elaborate stations are completely enclosed and can contain liquid as well as solid rodent baits (Fig. 12). A hinged lid with a child-proof latch can be used for convenience in inspecting permanent stations.

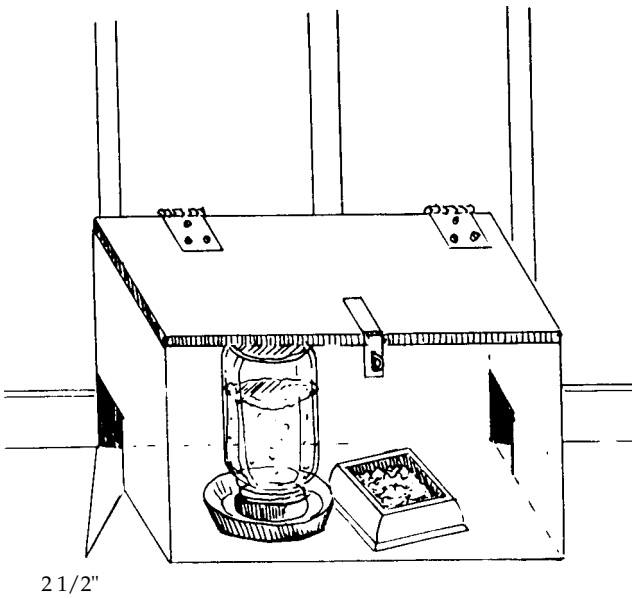


Fig. 12. A homemade rodent bait station can contain liquid as well as solid baits.

Bait stations for mice should have at least two openings approximately 1 inch (2.5 cm) in diameter. Locate the two holes on opposite sides of the station so that mice can see an alternate escape route as they enter the station.

Bait Station Maintenance. Baits must be fresh and of high quality. Mice may reject spoiled or stale foods. Provide enough fresh bait to allow rodents to eat all they want. When using rodenticides designed for continuous bait application (such as anticoagulants), bait station maintenance is essential to a successful baiting effort. When bait boxes are first put out, check them daily and add fresh bait as needed. After a short time, as rodent numbers and feeding decline, check the boxes once every 2 to 4 weeks. If the bait becomes moldy, musty, soiled, or insect-infested, empty the box and clean it, and then refill it with fresh bait. Dispose of spoiled or uneaten bait in accordance with the label. Follow all label directions for the product you are using.

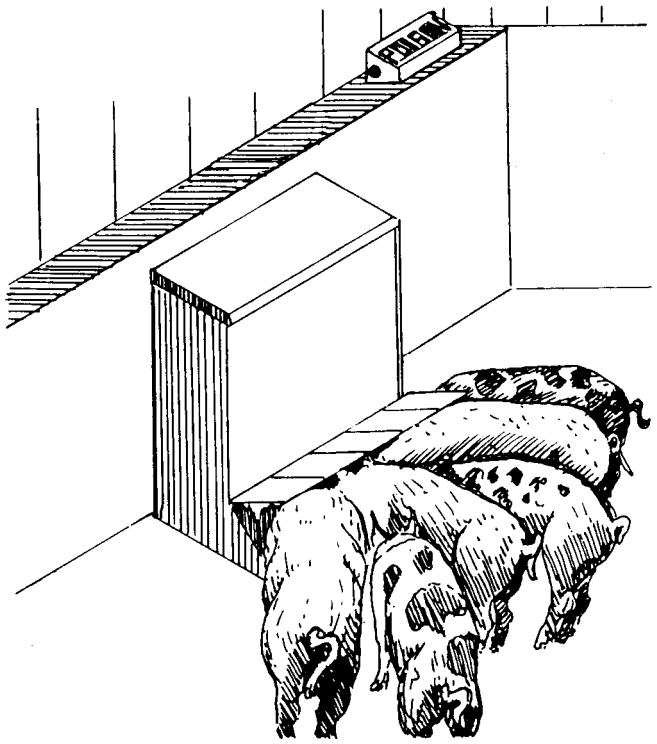


Fig. 13. Rodent bait box attached to the top of open dividing wall in a swine confinement facility. When used in such locations, bait boxes must be securely fastened and out of pigs' reach.

Placement of Bait Stations. House mice are active in a small area and lack notable food preferences. Therefore, proper placement of baits or bait stations is often more important than the type of bait used. Mice will not visit bait stations, regardless of their contents, if not conveniently located in areas where they are active.

Where possible, place bait between the rodents' source of shelter and their food supply. Put bait boxes near rodent burrows, against walls or along travel routes. Where mice are living in sacked or boxed feed on pallets, baits or traps may have to be placed on top of stacks or wedged in gaps within the stacks. In such situations, this "three dimensional" bait placement is important to obtain good control. Caution should be used in selecting control methods in such situations. Do not use baits that will contaminate foodstuffs. For safety, it may not be wise to use toxic baits in the vicinity of certain foodstuffs. Traps or glue boards may be used instead.

On farmsteads, bait station placement depends on building design and use. For example, in swine confinement buildings it may be possible to attach bait boxes to wall ledges or the top of pen dividing walls. Bait boxes may be placed in attics or along floors or alleys where rodents are active (Fig. 13). Rodent tracks visible on dusty surfaces and their droppings often give clues to where they are active.

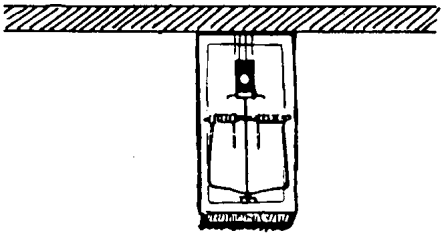
Never place bait stations where livestock, pets, or other animals can knock them over. Spilled bait may be a potential hazard, particularly to smaller animals.

Where buildings are not rodent-proof, permanent bait stations can be placed inside buildings, along the outside of building foundations, or around the perimeter. Bait stations will help keep rodent numbers at a low level when maintained regularly with fresh anticoagulant bait. Rodents moving in from nearby areas will be controlled before they can reproduce and cause serious damage.

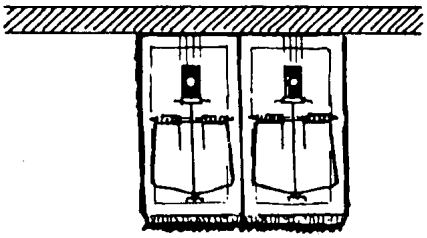
Tracking Powders. Toxic dusts or powders have been successfully used for many years to control mice and rats. When mice walk over a patch of toxic powder, they pick some of it up on their feet and fur and later ingest it while grooming. Tracking powders are useful in controlling mice where food is plentiful and good bait acceptance is difficult to achieve. Mice are more likely to ingest a lethal amount of a poorly accepted toxicant applied by this method than if it is mixed into a bait material. There is little likelihood of toxicant shyness developing when using tracking powders.

Because the amount of material a mouse may ingest while grooming is small, the concentration of active ingredient in tracking powders is considerably higher than in food baits that utilize the same toxicant. Therefore, these materials can be more hazardous than food baits. For the most part, tracking powders are used by professional pest control operators and others trained in rodent control. Tracking powders containing either zinc phosphide or anticoagulants are commercially available, although some are Restricted Use Pesticides.

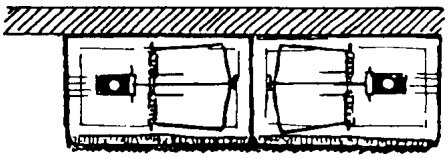
Place tracking powders along runways, in walls, behind boards along



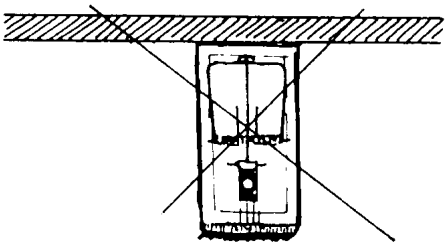
Single trap set with trigger next to wall.



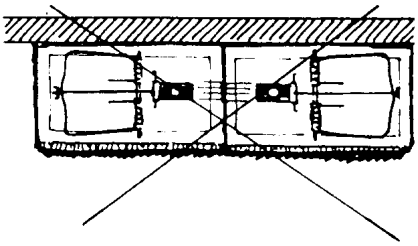
The double set increases your success.



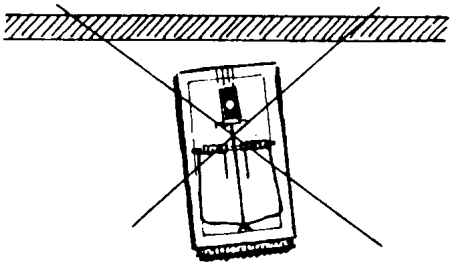
Double set placed parallel to the wall with triggers to the outside.



Wrong—trigger not next to wall.



Wrong—parallel set with triggers on the inside.



Wrong—trap too far from wall.

Fig. 14. Placement of snap traps.

walls, or on the floor of bait stations. Placement can be aided by using various types of sifters, shakers, or blowers. Dampness may cause the powder to cake and lessen its effectiveness. Care must be taken to place tracking powders only where they cannot contaminate food or animal feed, or where nontarget animals cannot come into contact with them. Do not place tracking powders where mice can track the material onto food intended for use by humans or domestic animals. Tracking powders are not generally recommended for use in and around homes because of the potential hazards to children and pets. Where possible, remove tracking powder after the rodent control program is completed. Tracking powders used in conjunction with baiting can provide very effective mouse control.

Fumigants

Fumigants (toxic gases) are most commonly used to control mice in structures or containers such as feed bins, railway cars, or other enclosed areas. Aluminum phosphide, chloropicrin, and methyl bromide are currently registered for this purpose. Some fumigant materials are registered for use in rodent burrows; however, house mouse burrows cannot be fumigated efficiently or economically because they are small and often difficult to find. Generally, control of house mice by fumigation is only practical and cost-effective in a very limited number of situations. Fumigants are hazardous materials and should be applied only by persons well trained in their use and who possess the necessary safety equipment.

Trapping

Trapping can be an effective method of controlling mice, but it requires more labor than most other methods. Trapping is recommended where poisons seem inadvisable. It is the preferred method to try first in homes, garages, and other small structures where there may be only a few mice present.

Trapping has several advantages: (1) it does not rely on inherently hazardous rodenticides; (2) it permits the user to view his or her success; and (3) it allows for disposal of the mice, thereby eliminating odor problems from decomposing carcasses that may remain when poisoning is done within buildings.

The simple, inexpensive, wood-based snap trap is available in most hardware and farm supply stores. Traps should be baited with a small piece of nutmeat, chocolate candy, dried fruit, or bacon tied securely to the trigger. Peanut butter or marshmallows also may be used as bait. Because mice are always in search of nesting materials, a small cotton ball will also work as a bait when attached securely to the trigger. Food baits that become stale lose their effectiveness.

Set traps close to walls, behind objects, in dark places, and in locations where mouse activity is seen. Place the traps so that when mice follow their natural course of travel (usually close to a wall) they will pass directly over the trigger (Fig. 14). Set traps so that the trigger is sensitive and will spring easily. Effectiveness can be increased by enlarging the trigger. Attach a square of cardboard, metal, or screen wire that fits just inside the wire deadfall (Fig. 15).

Use enough traps to make the campaign short and decisive. Mice seldom venture far from their shelter and food supply, so traps should be spaced no more than about 6 feet (1.8 m) apart in areas where mice are active. Although mice are not nearly as afraid of new objects as rats are, leaving the traps baited but unset until the bait is taken at least once will reduce the chance of mice escaping the trap and becoming trap-shy.

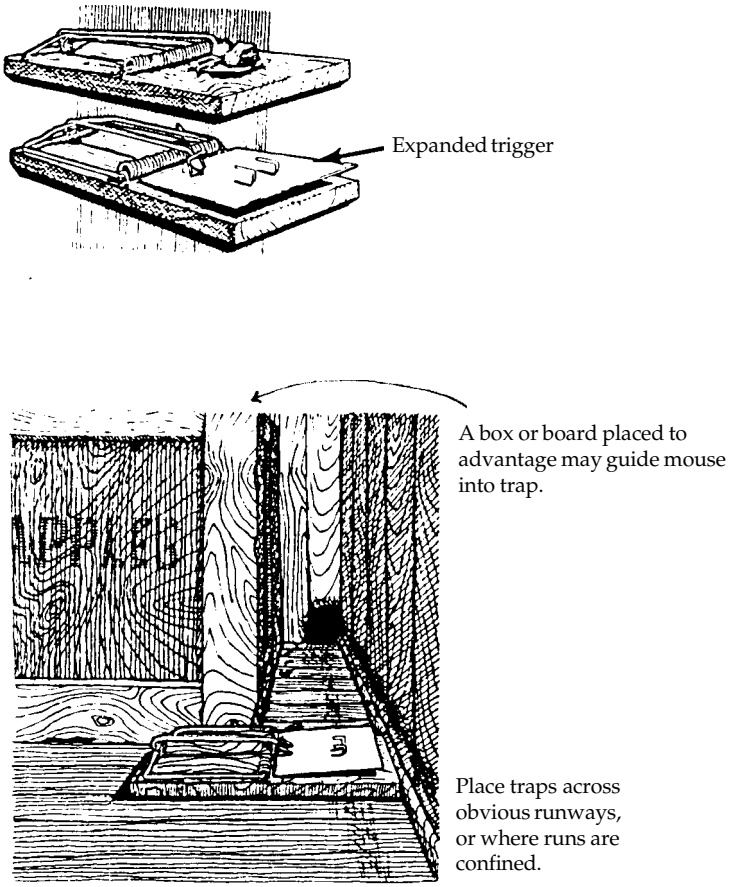


Fig. 15. Expanded-trigger traps, when properly placed, can be very effective.

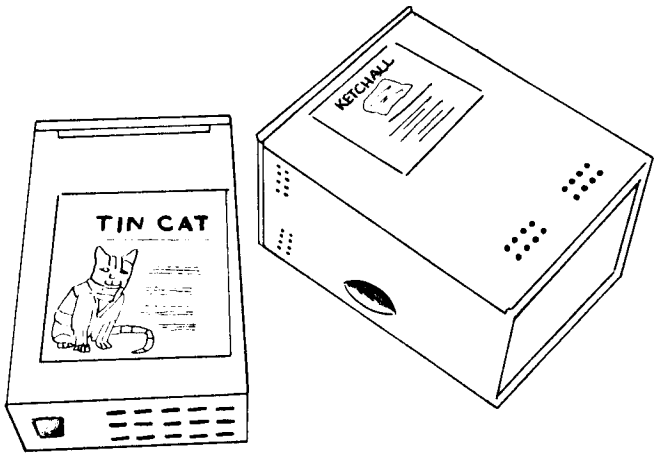


Fig. 16. Automatic multiple-capture mouse traps are commercially available (for example: *left*, Tin Cat®; *right*, Ketch-All®).

Multiple-capture (automatic) mouse traps such as the Ketch-All® and Victor Tin Cat® (Fig. 16) are available from some hardware and farm supply stores as well as from pest control equipment distributors. These traps work on the principle that mice enter small holes without hesitation. The Ketch-All® has a wind-up spring that powers a rotating mechanism. When triggered, the mechanism entraps mice in a holding compartment. The Tin Cat® has one-way doors that mice cannot exit. Such traps may catch many mice in a single setting, but should be checked and emptied periodically so that mice do not die of starvation or exposure in the traps.

Various types of box-type traps (Sherman-type and others) that capture one mouse at a setting are used primarily for research purposes. The desire to "build a better mousetrap" keeps a variety of traps of variable effectiveness coming and going on the retail market.

Keep traps reasonably clean and in good working condition. They can be cleaned with a hot detergent solution and a stiff brush. Human and dead-mouse odors on traps are not known to reduce trapping success.

An alternative to traps are glue boards, which catch and hold mice attempting to cross them, much the way flypaper catches flies. Place glue boards wherever mice travel—along walls or in established runways. Do not use glue boards where children, pets, or desirable wildlife can contact them. Glue boards lose their effectiveness in dusty areas unless covered, and temperature extremes may affect the tackiness of some glues. They are considered less effective for capturing rats than for mice. Glue boards can be purchased ready-to-use, or they can be made.

Euthanize live, trapped rodents by carbon dioxide asphyxiation or use a stick to kill them with sharp blows to the base of the skull. For further information on glue boards, see the section **Supplies and Materials.**

Other Methods

Some dogs and cats will catch and kill mice and rats. There are few situations, however, in which they will do so sufficiently to control rodent populations. Around most structures, mice can find many places to hide and rear their young out of the reach of such predators. Cats probably cannot eliminate existing mouse populations, but in some situations they may be able to prevent reinfestations once mice have been controlled. Farm cats, if sufficient in number and supplementally fed, may serve this function.

In urban and suburban areas, it is not uncommon to find rodents living in close association with cats and dogs, relying on cat and dog food for nourishment. Mice frequently live beneath dog houses and soon learn they can feed on their food when they are absent or asleep.

Economics of Damage and Control

Accurate data on mouse damage, control, and their cost are difficult to obtain. Estimates of losses of foodstuffs, structural damage, and the amount of labor and materials expended to control mice are usually only educated guesses.

In one survey of corn in a midwestern state, 76% of about 1,000 grain samples were contaminated with rodent droppings. Mouse droppings outnumbered rat droppings twelve to one. A house mouse produces about 36,000 droppings in a year's time. Mouse infestations are so widespread that droppings and hairs often end up in many types of food commodities intended for human use. Certain levels of rodent contamination are grounds for condemning food commodities.

Structural damage caused by rodents can be expensive. In recent years, the trend toward use of insulated confinement facilities to raise swine in the northern Great Plains has led to an increased amount of rodent damage. Mice, in particular, are very destructive to rigid foam, fiberglass batt, and other types of insulation in walls and attics of such facilities. In one small swine finishing building near Lincoln, Nebraska, rodent damage required the producer to spend $5,000 in repairs to the facility only 3 years after initial construction.

Acknowledgments

I thank Rex E. Marsh for reviewing a previous version of this chapter and providing many helpful comments. Portions of the recommendations on toxicant use are taken directly from his chapter **Roof Rats** in this manual. Other material contained in this chapter is derived from Brooks (1973), Marsh and Howard (1981), and Pratt et al. (1977), among other sources.

Figure 1 is from Schwartz and Schwartz (1981).

Figures 2, 5, and 15 were adapted from Pratt et al. (1977) by Jill Sack Johnson.

Figures 3 and 14 were adapted from Howard and Marsh (1981) by Jill Sack Johnson.

Figure 4 from Hygnstrom and Virchow (1992).

Figures 6, 7, and 8 were developed by Jill Sack Johnson.

Figures 9, 12, and 13 are by Frances I. Gould, University of Nebraska-Lincoln, Cooperative Extension.

Figures 10 and 11 were adapted from Pratt et al. (1977) by Frances I. Gould.

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Robert M. Timm
Superintendent and Extension Wildlife Specialist
Hopland Research and Extension Center
University of California
Hopland, California 95449

Walter E. Howard
Professor Emeritus
Department of Wildlife, Fisheries and Conservation Biology
University of California
Davis, California 95616

WHITE-FOOTED AND DEER MICE

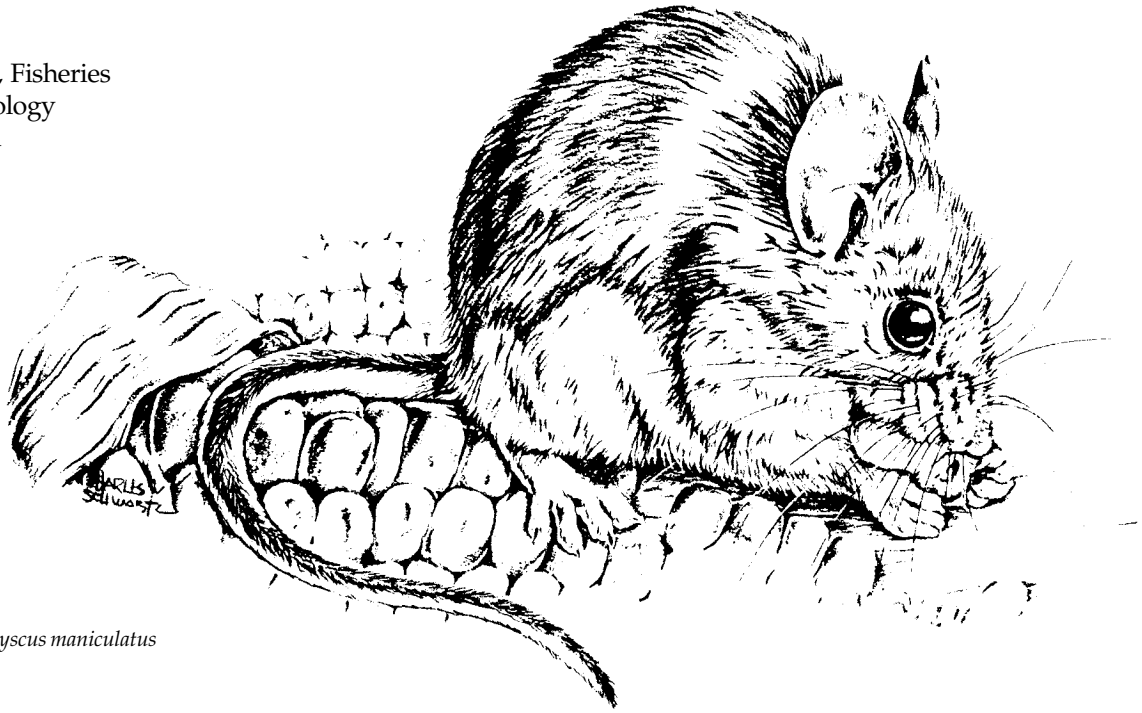


Fig. 1. The deer mouse, *Peromyscus maniculatus*

Damage Prevention and Control Methods

Exclusion

Rodent-proof construction will exclude mice from buildings and other structures.

Use hardware cloth (1/4-inch [0.6 cm] mesh) or similar materials to exclude mice from garden seed beds.

Habitat Modification

Store food items left in cabins or other infrequently used buildings in rodent-proof containers.

Store furniture cushions, drawers, and other items in infrequently used buildings in ways that reduce nesting sites.

Frightening

Not effective.

Repellents

Naphthalene (moth balls or flakes) may be effective in confined spaces.

Toxicants

Anticoagulants.

Zinc phosphide.

Fumigants

None are registered.

Trapping

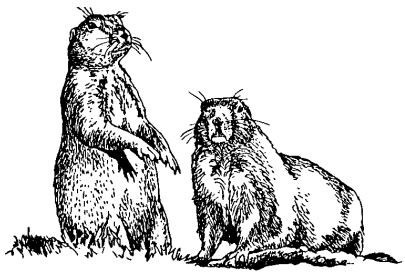
Snap traps.

Box- (Sherman) type traps.

Automatic multiple-catch traps.

Other Methods

Alternative feeding: Experiments suggest that application of sunflower seed may significantly reduce consumption of conifer seed in forest reseeding operations, although the tests have not been followed to regeneration.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
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Great Plains Agricultural Council
Wildlife Committee

Identification

Fifteen species of native mice of the genus *Peromyscus* may be found in the United States. The two most common and widely distributed species are the deer mouse (*Peromyscus maniculatus*, Fig. 1) and the white-footed mouse (*P. leucopus*). This chapter will deal primarily with these species. Collectively, all species of *Peromyscus* are often referred to as "white-footed mice" or "deer mice." Other species include the brush mouse (*P. boylei*), cactus mouse (*P. eremicus*), canyon mouse (*P. crinitus*), cotton mouse (*P. gossypinus*), golden mouse (*P. nuttalli*), piñon mouse (*P. truei*), rock mouse (*P. difficilis*), white-ankled mouse (*P. pectoralis*), Merriam mouse (*P. merriami*), California mouse (*P. californicus*), Sitka mouse (*P. sitkensis*), oldfield mouse (*P. polionotus*), and the Florida mouse (*P. floridanus*).

All of the *Peromyscus* species have white feet, usually white undersides, and brownish upper surfaces. Their tails are relatively long, sometimes as long as the head and body. The deer mouse and some other species have a distinct separation between the brownish back and white belly. Their tails are also sharply bicolored. It is difficult even for an expert to tell all of the species apart.

In comparison to house mice, white-footed and deer mice have larger eyes and ears. They are considered by most people to be more "attractive" than house mice, and they do not have the characteristic mousy odor of house mice. All species of *Peromyscus* cause similar problems and require similar solutions.

Range

The deer mouse is found throughout most of North America (Fig. 2). The white-footed mouse is found throughout the United States east of the Rocky Mountains except in parts of the Southeast (Fig. 2).

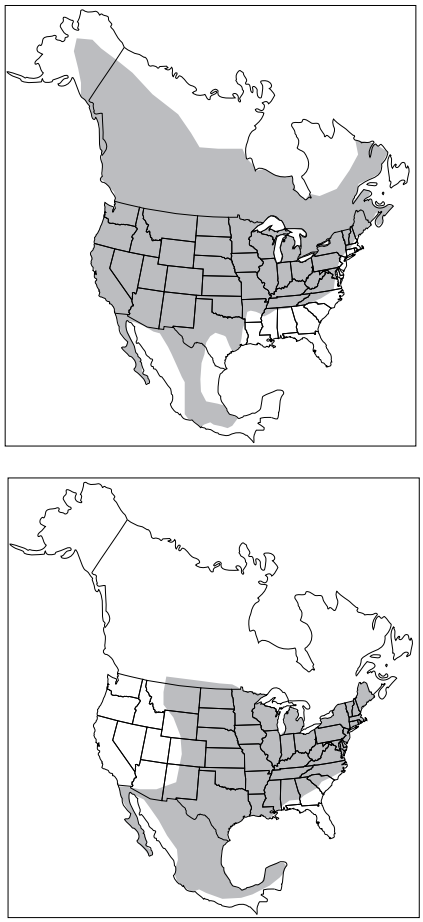

Fig. 2. Range of the deer mouse (*P. maniculatus*) (a) and white-footed mouse (*P. leucopus*) (b) in North America.

The brush mouse is found from southwestern Missouri and northwestern Arkansas through Oklahoma, central and western Texas, New Mexico, southwestern Colorado, Utah, Arizona, and California. The cactus mouse is limited to western Texas, southern New Mexico, Arizona (except the northeast portion), and southern California. The canyon mouse occurs in western Colorado, northwestern New Mexico, northern and western Arizona, Utah, Nevada, southern California, southeast Oregon, and southwestern Idaho.

The cotton mouse is found only in the southeastern United States from east Texas and Arkansas through southeastern Virginia. The golden mouse occupies a similar range but it extends slightly farther north.

The piñon mouse is found from southwestern California through the southwestern United States to the Texas panhandle. The rock mouse is limited to Colorado, southeastern Utah, eastern Arizona, New Mexico, and the far western portion of Texas. The white-ankled mouse is found only in parts of Texas and small areas in southern New Mexico, southern Oklahoma, and southern Arizona.

The Merriam mouse is limited to areas within southern Arizona. The California mouse ranges from San Francisco Bay to northern Baja California, including parts of the southern San Joaquin Valley. The Sitka mouse is found only on certain islands of Alaska and British Columbia.

The oldfield mouse is distributed across eastern Alabama, Georgia, South Carolina, and Florida. The Florida mouse, as its name indicates, is found only in Florida.

Habitat

The deer mouse occupies nearly every type of habitat within its range, from forests to grasslands. It is the most widely distributed and abundant mammal in North America.

The white-footed mouse is also widely distributed but prefers wooded or brushy areas. It is sometimes found in open areas.

The other species of *Peromyscus* have somewhat more specialized habitat preferences. For example, the cactus mouse occurs in low deserts with sandy soil and scattered vegetation and on rocky outcrops. The brush mouse lives in chaparral areas of semi-desert regions, often in rocky habitats.

Food Habits

White-footed and deer mice are primarily seed eaters. Frequently they will feed on seeds, nuts, acorns, and other similar items that are available. They also consume fruits, insects and insect larvae, fungi, and possibly some green vegetation. They often store quantities of food near their nest sites, particularly in the fall when seeds, nuts, or acorns are abundant.

General Biology, Reproduction, and Behavior

White-footed and deer mice are mostly nocturnal with a home range of 1/3 acre to 4 acres (0.1 to 1.6 ha) or larger. A summer population density may reach a high of about 15 mice per acre (37/ha).

In warm regions, reproduction may occur more or less year-round in some species. More typically, breeding occurs from spring until fall with a summer lull. This is especially true in cooler climates. Litter size varies from 1 to 8 young, but is usually 3 to 5. Females may have from 2 to 4 or more litters per year, depending on species and climate.

During the breeding season, female white-footed and deer mice come into heat every fifth day until impregnated. The gestation period is usually 21 to 23 days, but may be as long as 37 days in nursing females. Young are weaned when they are 2 to 3 weeks old and become sexually mature at about 7 to 8 weeks of age. Those born in spring and summer may breed that same year.

Mated pairs usually remain together during the breeding season but may take new mates in the spring if both survive the winter. If one mate dies, a new one is acquired. Family groups usually nest together through the winter. They do not hibernate but may become torpid for a few days when winter weather is severe.

Nests consist of stems, twigs, leaves, roots of grasses, and other fibrous materials. They may be lined with fur, feathers, or shredded cloth. The deer mouse often builds its nest underground in cavities beneath the roots of trees or shrubs, beneath a log or board, or in a burrow made by another rodent. Sometimes deer mice nest in aboveground sites such as a hollow log or fencepost, or in cupboards and furniture of unoccupied buildings.

White-footed mice spend a great deal of time in trees. They may use abandoned bird or squirrel nests, adding a protective "roof" of twigs and other materials to completely enclose a bird's nest (Fig. 3). Like deer mice, they nest at or just below ground level or in buildings.

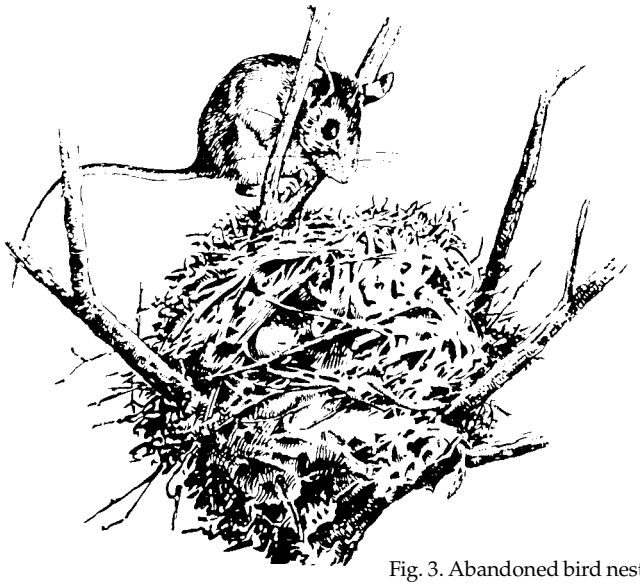

Fig. 3. Abandoned bird nests are frequently roofed and converted into white-footed mouse (*P. leucopus*) homes.

Damage and Damage Identification

The principal problem caused by white-footed and deer mice is their tendency to enter homes, cabins, and other structures that are not rodent-proof. Here they build nests, store food, and can cause considerable damage to upholstered furniture, mattresses, clothing, paper, or other materials that they find suitable for their nest-building activities. Nests, droppings, and other signs left by these mice are similar to those of house mice. White-footed and deer mice have a greater tendency to cache food supplies, such as acorns, seeds, or nuts, than do house mice. White-footed and deer mice are uncommon in urban or suburban residential areas unless there is considerable open space (fields, parks) nearby.

Both white-footed and deer mice occasionally dig up and consume newly planted seeds in gardens, flowerbeds, and field borders. Their excellent sense of smell makes them highly efficient at locating and digging up buried seed. Formerly, much reforestation was attempted by direct seeding of clear-cut areas, but seed predation by deer mice and white-footed mice, and by other rodents and birds, caused frequent failure in the regeneration. For this reason, to reestablish Douglas fir and other commercial timber species today, it is often necessary to hand-plant seedlings, despite the increased expense of this method.

In mid-1993, the deer mouse (*P. maniculatus*) was first implicated as a potential reservoir of a type of hantavirus responsible for an adult respiratory distress syndrome, leading to several deaths in the Four Corners area of the United States. Subsequent isolations of the virus thought responsible for this illness have been made from several Western states. The source of the disease is thought to be through human contact with urine, feces, or saliva from infected rodents.

Legal Status

White-footed and deer mice are considered native, nongame mammals and receive whatever protection may be afforded such species under state or local laws. It is usually permissible to control them when necessary, but first check with your state wildlife agency.

Damage Prevention and Control Methods

Exclusion

Rodent-proof construction is the best and most permanent method of preventing rodents from entering homes, cabins, or other structures. White-footed and deer mice require measures similar to those used for excluding house mice. No openings larger than 1/4 inch (0.6 cm) should be left unmodified. Mice will gnaw to enlarge such openings so they can gain entry. For additional information, see the chapter **Rodent-proof Construction** and **Exclusion Methods**.

Use folded hardware cloth (wire mesh) of 1/4 inch (0.6 cm) or smaller to protect newly seeded garden plots. Homemade wire-screen caps or bowls can be placed over seeded spots. Bury the edges of the wire several inches beneath the soil. Plastic strawberry-type baskets inverted over seeded spots serve a similar purpose.

Habitat Modification

Store foodstuffs such as dry pet food, grass seed, and boxed groceries left in cabins in rodent-proof containers.

Mouse damage can be reduced in cabins or other buildings that are used only occasionally, by removing or limiting nesting opportunities for mice. Remove padded cushions from sofas and chairs and store them on edge, separate from one another, preferably off the floor. Remove drawers in empty cupboards or chests and reinsert them upside-down, eliminating them as suitable nesting sites. Other such techniques can be invented to outwit mice. Remember that white-footed and deer mice are excellent climbers. They frequently enter buildings by way of fireplace chimneys, so seal off fireplaces when not in use.

When cleaning areas previously used by mice, take precautions to reduce exposure to dust, their excreta, and carcasses of dead mice. Where deer mice or related species may be reservoirs of hantaviruses, the area should be disinfected by spraying it thoroughly with a disinfectant or a solution of diluted household bleach prior to beginning any swepping, vacuuming, or handling of surfaces or materials with which mice have had contact. Use appropriate protective clothing, including vinyl or latex gloves. Contact the Centers for Disease Control (CDC) Hotline for current recommendations when handling rodents or cleaning areas previously infested.

Frightening

There are no methods known for successfully keeping white-footed or deer mice out of structures by means of sound. Ultrasonic devices that are commercially sold and advertised to control rodents and other pests have not proven to give satisfactory control.

Repellents

Moth balls or flakes (naphthalene) may effectively repel mice from closed areas where a sufficient concentration of the chemical can be attained in the air. These materials are not registered for the purpose of repelling mice, however.

Toxicants

Anticoagulants. Anticoagulant baits such as warfarin, diphacinone, chlorophacinone, brodifacoum, and bromadiolone are all quite effective on white-footed and deer mice, although they are not specifically registered for use on these species. Brodifacoum and bromadiolone, unlike the other anticoagulants, may be effective in a single feeding. If baiting in and around structures is done for house mice in accordance with label directions, white-footed and deer mice usually will be controlled. No violation of pesticide laws should be involved since the "site" of bait application is the same.

Behavioral differences may result in white-footed and deer mice carrying off and hoarding more bait than house mice normally do. For this reason, loose-grain bait formulations or secured paraffin wax bait blocks may be more effective, since these cannot be easily carried off. Cabins should be baited before being left unoccupied. For further information on anticoagulant baits and their use, see the chapter **House Mice.**

Zinc phosphide. Various zinc phosphide grain baits (1.0% to 2.0% active ingredient) are registered for the control of *Peromyscus* as well as voles and for post-harvest application in orchards and at other sites. Zinc phosphide is a single-dose toxicant, and all formulations are Restricted Use Pesticides. Follow label directions when applying. There are few damage situations where control of white-footed or deer mice require the use of zinc phosphide.

Fumigants

None are registered for white-footed or deer mice. Because of the species' habitat, there are few situations where fumigation would be practical or necessary.

Trapping

Ordinary mouse snap traps, sold in most grocery and hardware stores, are effective in catching white-footed and deer mice. Bait traps with peanut butter, sunflower seed, or moistened rolled oats. For best results, use several traps even if only a single mouse is believed to be present. Set traps as you would for house mice: against walls, along likely travel routes, and behind objects. Automatic traps designed to live-capture several house mice in a single setting also are effective against white-footed and deer mice. They should be checked frequently to dispose of captured mice in an appropriate manner: euthanize them with carbon dioxide gas in a closed container, or release them alive into an appropriate location where they won't cause future problems. For further details on trapping, see **House Mice.**

Other Methods

Recent research has revealed the possibility that supplemental feeding at time of seeding can increase survival of conifer seed by reducing predation by deer mice, although the tests were not carried out to germination.

Sunflower seed, and a combination of sunflower and oats, were applied along with Douglas fir and lodgepole pine seed in ratios ranging from two to seven alternate foods to one conifer seed. Significantly more conifer seeds survived mouse predation for the 6- and 9-week test periods than without the supplemental feeding. For further details on the experimental use of this technique, see Sullivan and Sullivan (1982a and 1982b).

Economics of Damage and Control

Damage by both white-footed and deer mice is usually a nuisance. When mice destroy furniture or stored materials, the cost of such damage depends upon the particular circumstances. The greatest economic impact of deer mice is their destruction of conifer seed in forest reseeding operations. In west coast forest areas, *Peromyscus* seed predation has resulted in millions of dollars worth of damage and has been documented to have been a serious problem since the early 1900s. New efficacious, cost-effective methods of reducing this seed predation are needed.

Acknowledgments

Much of the information in this chapter was taken from Marsh and Howard (1990) and from Schwartz and Schwartz (1981).

Figures 1 through 3 from Schwartz and Schwartz (1981).

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Editors
Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Dan L. Campbell
Project Leader
Olympia Field Station
Denver Wildlife Research Center
USDA-APHIS-
Animal Damage Control
Olympia, Washington 98512

MOUNTAIN BEAVERS

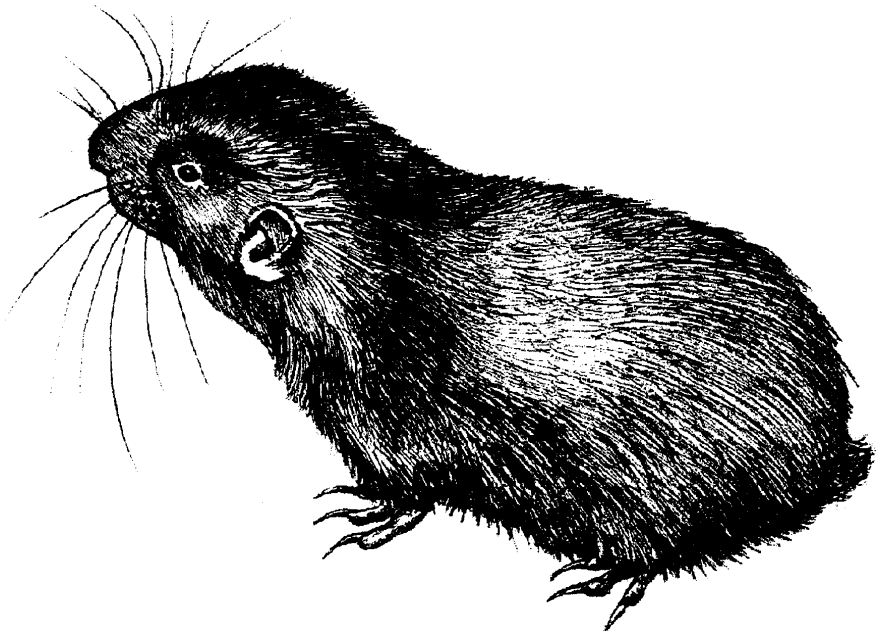

Fig. 1. Mountain beaver, *Aplodontia rufa*

Damage Prevention and Control Methods

Exclusion

Use plastic mesh seedling protectors on small tree seedlings. Wire mesh cages are somewhat effective, but large diameter cages are expensive and allow animals to enter them.

Exclusion from large areas with buried fencing is impractical for most sites.

Cultural Methods/Habitat Modification

Plant large tree seedlings that will tolerate minor damage.

Burn or remove slash to reduce cover.

Tractor scarification of sites will destroy burrow systems.

Remove underground nests to reduce reinvasion.

Frightening

Not applicable.

Repellents

36% Big Game Repellent Powder has been registered for mountain beaver in Washington and Oregon.

Toxicants

A pelleted strychnine alkaloid bait was registered in Oregon but may be discontinued.

Fumigants

None are registered.

Trapping

No. 110 Conibear® traps placed in main burrows are effective but may take nontarget animals using burrows, including predators.

Welded-wire, double-door live traps are effective and selective, but are primarily useful for research studies and removal of animals in urban/residential situations.

Shooting

Not applicable.

Identification

The mountain beaver (*Aplodontia rufa*, Fig. 1) is a medium-sized rodent in the family Aplodontiadae. There are no other species in the family. Average adults weigh 2.3 pounds (1,050 g) and range from 1.8 to 3.5 pounds (800 to 1,600 g). Average overall length is 13.5 inches (34 cm), including a rudimentary tail about 1 inch (2.5 cm) long. The body is stout and compact. The head is relatively large and wide and blends into a large neck with no depression where it joins the shoulders. The eyes and ears are relatively small and the cheeks have long silver "whiskers." The hind feet are about 2 inches (5 cm) long and slightly longer than the front feet (Fig. 2). Mountain beavers often balance on their hind feet while feeding. The front feet are developed for grasping and climbing.

Adults are grayish brown or reddish brown. The underfur on the back and sides is charcoal with brown tips; guard hair is dark brown or black with

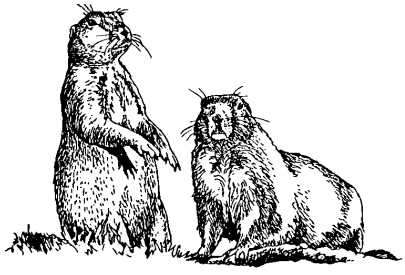

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Fig. 2. Mountain beaver feet are developed for burrowing and climbing.

silver tips. Ventrally, the underfur is gray with few guard hairs. A whitish spot of bare skin is present at the base of the ears. The feet are lightly furred on top and bare on the soles. Young animals are generally darker than adults. Males have a baculum (a bone about 1 inch [2.5 cm] long in the penis). Mature females generally have a patch of dark-colored underfur around each of the six nipples.

Range

Mountain beavers are found in the Pacific coastal region from southern British Columbia to northern California (Fig. 3). They range westward from the Cascade Mountains and southward into the Sierras. Numbers are higher and populations are more continuous in the coastal Olympic Mountains and in the coast range of Washington and Oregon than elsewhere. In the southern limit of its range, populations are more scattered but sometimes locally abundant.

Habitat

Mountain beaver habitat is characteristically dominated by coastal Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*). Within this zone, mountain beavers often favor moist ravines and wooded or brushy hillsides or flats that are not subjected to continuous flooding. Although frequently found near small streams, they are not limited to those sites except in more arid regions. Active burrows may carry water runoff after heavy rains, but mountain beavers will vacate burrow systems that become flooded. Mountain beavers do not require free water; they obtain adequate moisture from the vegetation they eat.

Mountain beavers occupy mature forests usually in openings or in thinned stands where there is substantial vegetation in the understory. They usually leave stands where the canopy has closed and ground vegetation has become sparse. Preferred habitats in forested sites are often dominated by red alder (*Alnus rubra*), which the animals promote by preferentially feeding on conifers and other vegetation. These sites are often dominated by an understory of sword fern (*Polystichum munitum*), a preferred food of mountain beavers. Stands of bracken fern (*Pteridium aquilinum*) are also favored by mountain beavers. Preferred shrub habitats include salmonberry (*Rubus spectabilis*), huckleberry (*Vaccinium parvifolium*), salal (*Gaultheria shallon*), and Oregon grape (*Berberis nervosa*). Small trees often found cut by mountain beavers include vine maple (*Acer circinatum*) and cascara (*Rhamnus purshiana*). These species are often intermingled with 30 or more other plant species including forbs, grasses, and sedges.

Fig. 3. Approximate range of mountain beavers in North America.

Food Habits

The food habits of mountain beavers are closely tied to the dominant vegetation in their habitat. Sword fern and bracken fern are preferred when available. Douglas-fir, hemlock, western red cedar (*Thuja plicata*), and red alder are all commercial tree species that are cut and eaten by mountain beavers. Other species found in their habitat are either eaten or used for construction of nests. Most feeding occurs above ground within 50 feet (15.2 m) of burrows, although occasionally mountain beavers may travel several hundred feet from burrows. They routinely climb shrubs and trees 8 feet (2.4 m) or higher to cut off branches up to 3/4 inch (1.9 cm) in diameter, where they leave cut stubs of branches on trees. Mountain beavers also girdle the base of tree stems and will feed on stems up to 6 inches (15 cm) in diameter, as well as the root systems of large trees. The bark is found in the stomach contents of animals collected in midwinter. Woody stems are often girdled and cut into about 6-inch (15-cm) lengths. Food and/or nest items are often stacked at burrow entrances (Fig. 4) but are sometimes carried directly to food caches or nests. Plant material is occasionally eaten outside the burrow but is usually eaten at the food cache, in nests, or in the burrow. Mountain beavers practice coprophagy (consumption of feces) and select soft over hard pellets.

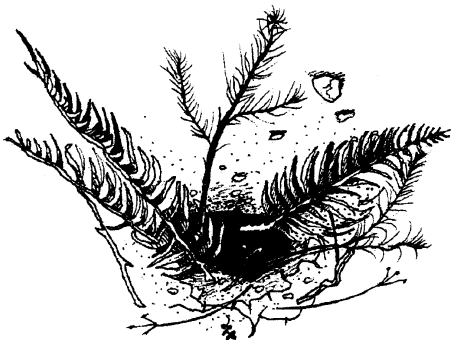

Fig. 4. Sword fern and Douglas-fir piled at the entrance of a mountain beaver burrow.

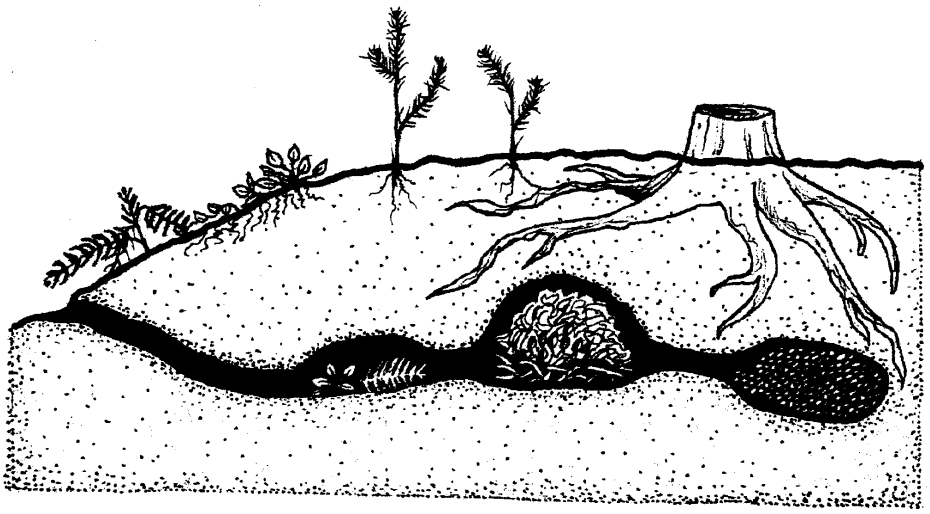

Fig. 5. Cross section of part of a mountain beaver burrow system including food cache, nest, and fecal chamber.

General Biology, Reproduction, and Behavior

Mountain beavers dig extensive individual burrow systems that generally are 1/2 to 6 feet (0.2 to 1.8 m) deep with 10 to 30 exit or entrance holes that are usually left open. The ground surface often caves in where burrows are shallow. There are many exit burrows forming T-shaped junctions with a main burrow. These exits may be horizontal or even vertical. Burrows are often found under old logs and are sometimes on the surface in logging debris. Mountain beavers seldom make obvious trails through vegetation. Most activity is at night and surface travel is usually near their burrows. Sometimes they are seen during daylight in dense surface vegetation several feet from burrow openings. Burrow systems usually cover a 1/4 acre (0.1 ha) or more and may intersect with burrow systems of adjacent individuals. Each system is apparently defended against neighboring mountain beavers. When an animal leaves a system or dies, the system is often quickly reoccupied by another mountain beaver.

Each burrow system contains an underground dome-shaped chamber with a nest, usually about 3 feet (1 m) below ground level (Fig. 5). Nests may vary from 1 to 9 feet (0.3 to 3 m) deep and are entered by one or several entrances. Nest chambers are usually about 2 feet (0.6 m) in diameter and 1 to 2 feet (0.3 to 0.6 m) high. The dome is hardened by packing the soil, apparently with the front feet, causing the ceiling to become a hardened shell. Water entering from above travels along this shell to the edges or floor of the chamber. The floor is often covered with 1 to 2 inches (2 to 5 cm) of coarse sticks to facilitate drainage. On top of the sticks is a variety of dry vegetation that closely surrounds a sleeping mountain beaver. A nest may consist of several cubic feet of dry and nearly dry vegetation. The burrow system also includes smaller chambers or widened burrows used as food caches. A fecal chamber, usually present within a few yards (1 to 3 m) of the nest chamber, is packed with fecal pellets. Fecal deposit chambers may be larger than the nest chamber, representing many years' use of the nest and burrow system.

In the spring and summer, mountain beavers periodically remove molded and partially eaten vegetation from their food caches. Most soil excavation occurs during dry periods from spring to fall. Vegetation is cut year-round, but activity outside burrows and away from the nest is curtailed during subfreezing temperatures. Portions of a burrow may not be used daily, but active burrows in a burrow system are usually used at least weekly.

The habit of stacking cut vegetation at burrow openings has been considered a means to lower its moisture content before taking it into humid food caches or relatively dry nest chambers. Mountain beavers, however, do not always stack cut vegetation and often cut it during periods of continuous rainfall and high humidity. Occasionally there may be 20 or 30 fern fronds or several tree seedlings stacked at burrow openings. The animals usually are quick to carry away small bundles of sword fern that they have placed inside the burrow opening. Some items such as grasses and trailing blackberry vines are cut but are seldom stacked at openings.

Little is known about mountain beaver behavior during the breeding season. Breeding activity occurs mainly from January to March with gestation lasting about 30 days. Young are born blind and hairless, weighing about 3/4 ounce (20 g). They develop incisors at about 30 days and are weaned at about 8 weeks. Young animals are often active in May. Females apparently do not bear young until 2 years of age.

Territorial behavior usually limits mountain beaver population densities to about 4 per acre (10/ha) although densities may be higher in some areas. Densities are generally higher in May and June when young are still active within burrow systems. In winter, average population densities in large reforestation tracts (more than 100 acres [40 ha]) seldom exceed 2 animals per acre (5/ha).

Several predators prey on mountain beavers. Above ground, the main predator, when present, is probably the bobcat (*Felis rufus*). Coyotes (*Canis latrans*) and great horned owls (*Bubo virginianus*) are other major large predators. In burrow systems, mink (*Mustela vison*) and long-tailed weasels (*Mustela frenata*) are the main predators. Weasel predation is probably limited to young or subadult animals less able to defend themselves.

Mountain beavers appear relatively free of diseases and internal parasites. Animals in western Washington were checked as possible carriers of plague but were found negative. A large flea (*Hystrichopsylla schefferi*) unique to mountain beavers is common on the animals but is not known to be a problem for humans. Mites (*Acarina* spp.) often infest the ear and eye region.

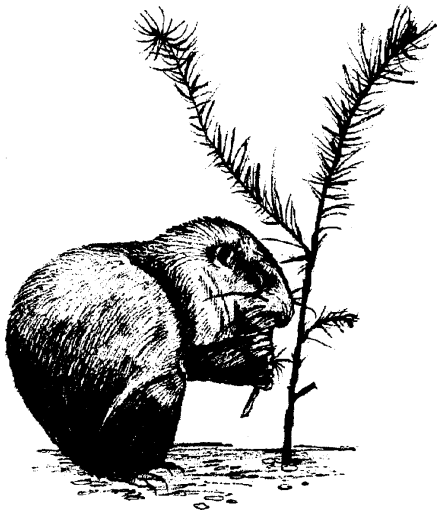

Fig. 6. Mountain beaver in feeding position.

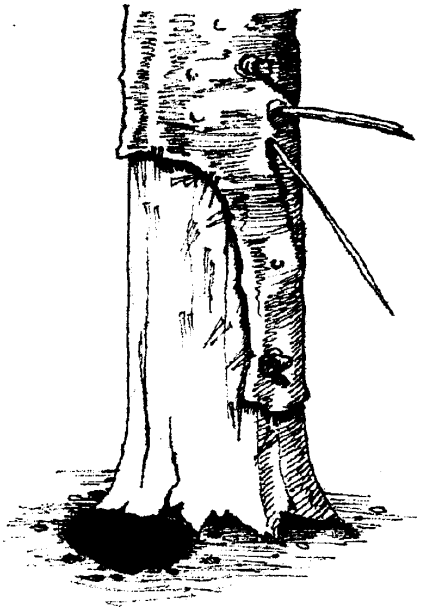

Fig. 7. Mountain beaver–girdled conifer tree.

Damage and Damage Identification

Mountain beavers have damaged an estimated 300,000 acres (120,000 ha) of commercial coniferous tree species in western Washington and Oregon. Much of the affected land has the potential to produce timber values of over $10,000 an acre. The damage period extends to about 20 years after planting. The major losses occur from cutting tree seedlings during the first year after planting (Fig. 6). Secondary damage occurs during the next 5 years to surviving tree seedlings, followed by stem girdling and root damage for the next 10 to 20 years. Increased need for weed and brush control and occasional replanting costs add to the economic losses caused by mountain beavers.

Damage to conifer seedlings is identified by angular rough cuts on stems 1/4 to 3/4 inches (0.6 to 1.9 cm) in diameter. Mountain beavers climb larger trees and cut stems near the tips. Limbs are often cut a few inches from the stem. Small trees are usually cut near ground level while others may be cut several feet up the stem. Seedling damage occurs primarily in winter and early spring, but often continues throughout the year.

Most stem-girdling damage is at the base of 3- to 6-inch (7- to 15-cm) diameter stems (Fig. 7). Girdling damage can be distinguished from that caused by bears or porcupines in that mountain beavers do not leave pieces of bark scattered on the ground and they cut the bark smoothly along the edges. Girdling damage to older stems is more difficult to distinguish, but it can be verified by examining burrows near tree trunks where fresh girdling can be seen on the roots.

Root girdling may occur at any age, but small roots are usually cut instead of girdled. Trees with stems over 6 inches (15 cm) in diameter may die due to extreme root girdling. Root girdling may allow tree root pathogens to become established in individual trees and spread to other trees. It occurs in winter and spring, and may occur in other seasons.

Mountain beaver damage in 10- to 15-year or older stands appears to be increasing and is of great concern because the crop trees are often selected at this time for precommercial thinning. Stem and root girdling may affect over 50% of the trees in a stand. Managers cannot achieve proper spacing in these damaged stands, and damage may continue on trees left as crop trees.

Damage to coniferous species is considered detrimental to forest production and can have long-term effects on habitats. This damage to commercial crops and other vegetation, however, does provide diversity of cover for other wildlife. In one area on the Olympic Peninsula in Washington, the excessive damage to conifers by mountain beavers caused a manager to change the area designation from reforestation land to wildlife habitat.

Legal Status

Mountain beavers are generally considered unprotected nongame species. Individuals wanting to control mountain beavers should consult their state fish and game agency to determine current regulations. A subspecies in California is considered endangered. Information on registered pesticides is available from the state's Department of Agriculture.

Damage Prevention and Control Methods

Exclusion

Small diameter plastic mesh seedling protectors (Fig. 8) will protect most conifer seedlings. Most are effective until the seedlings grow taller than the tube height. The relatively small (1-to 3-inch [2.5- to 7.6-cm]) diameter tubes

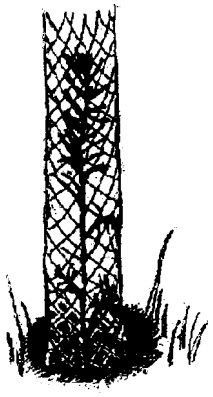

Fig. 8. Plastic mesh seedling protector.

do not protect much competing vegetation and also allow lateral branches to grow through the mesh. The advantage of plastic mesh protectors over some other control methods is that they provide protection from a variety of animals including deer (*Odocoileus* spp.), hares (*Lepus* spp.), elk (*Cervus* spp.), and voles (*Microtus* spp.). The cost of installation can be high, but can be reduced if done at the time of planting. Tree seedlings that become established and reach 30 inches (76 cm) or more in height are less susceptible to damage.

Plastic mesh seedling protectors photodegrade and deteriorate after several years. Although they expand with stem growth, they probably provide little protection from girdling of large diameter stems by mountain beavers.

Wire mesh cages 1 to 3 feet (0.3 to 1 m) in diameter will protect individual trees but are expensive and may be climbed over and burrowed under. These cages also allow competing vegetation to be protected and often cause poor tree growth. The wire used in these cages may injure tree growth if cages are tipped or come into contact with the tree stem.

Cultural Methods

Plant large tree seedlings to improve survival of the trees in sites occupied by mountain beavers. Larger stems are less subject to being clipped at ground level. Although large seedlings may be seriously damaged, enough foliage often remains after damage to provide for regrowth and survival after later damage. Damage-resistant trees should be about 2 feet (0.6 m) tall and have 1/2-inch (1.3-cm) or larger diameter stems at the base. Trees should be planted away from burrow openings so that mountain beavers will find them less convenient to cut.

Prescribed slash burning before planting may reduce mountain beaver populations by reducing available forage and increasing predation. Extremely hot fires may cause some mortality, but most mountain beavers will remain protected in their burrows. Reduction in available forage after fire may cause mountain beavers to travel farther from burrows and subject them to higher levels of predation. Legal restrictions or other practices that inhibit prescribed burning may favor mountain beaver populations.

Mountain beaver burrow systems may be destroyed by tractor scarification on level or moderate slopes when done to remove logging debris for replanting or to convert brush fields to plantations. This method requires the use of toothed land clearing blades to rip soil and destroy burrows. It seldom removes the deeper nest chambers but can make the area unattractive to mountain beavers. Avoid piling soil and wood debris, both of which will attract mountain beavers. Wood debris piles should be burned when possible and soil leveled.

Removal of nest chambers after population reduction will reduce reinvasion of the burrow systems by 50% or more. Practical methods for locating and removing nest chambers need further study.

Localized control of plants such as sword fern, bracken fern, or salal may reduce the attractiveness of an area to mountain beavers, but more study is necessary before methods can be recommended. Use caution when applying herbicides to avoid causing increased feeding pressure on conifers by suddenly removing the availability of other forage plants. In such situations, tree seedlings may require protection with plastic mesh seedling protectors.

Fig. 9. Application of powdered repellent to conifer seedling.

Repellents

Coniferous seedlings subject to mountain beaver damage may be treated with repellents, but they require special application procedures to assure the plant stem is treated near the base (Fig. 9). The effectiveness of a repellent can be enhanced by conditioning the mountain beavers to the repellent. Treat cull seedlings with the same repellent and place them in active burrows. This practice has caused mountain beavers to avoid both treated and untreated planted seedlings for up to a year after planting. The only repellent that has been registered for mountain beavers in Washington and Oregon is 36% Big Game Repellent Powder (BGR-P), originally registered only for big game. Thiram (tetramethylthiuram disulfide) is another repellent registered for hares, rabbits (*Sylvilagus* spp.), and big game that has been effective against mountain beavers. Repellents may be of most value where they cause a long-term avoidance. The placement of repellent-treated cull tree seedlings in burrows at time of planting and treating significantly improves repellent efficacy.

Toxicants

A pelleted 0.31% strychnine bait (Boomer-Rid®) has been registered in Oregon for control of mountain beavers. Recent field tests in Washington and Oregon, however, showed marginal efficacy in late winter with Boomer-Rid®. Pelleted bait is placed by hand inside main burrows, using about five baits each in 10 burrow openings in each system. The registered label allows 1/2 to 1 1/2 pounds of bait per acre (0.6 to 1.7 kg/ha). The bait formulation contains waterproofing binders that tolerate wet burrow conditions.

Experimental zinc phosphide-treated apple bait was poorly accepted by mountain beavers and was potentially hazardous to bait handlers. The treated bait was readily eaten by black-tailed deer (*Odocoileus hemionus columbianus*) and could present a hazard.

Baiting is severely restricted in areas frequented by endangered species such as northern spotted owls (*Strix occidentalis caurina*), and bald eagles (*Haliaeetus leucocephalus*).

Fumigants

Fumigants are generally ineffective because of the open, well-ventilated structure of the mountain beaver burrow systems. Aluminum phosphide that was activated when mountain beavers pulled pellets attached to vegetation into the nest area was only partially effective. The use of carbon monoxide gas cartridges and carbon monoxide gas have been unsuccessful in controlling mountain beavers. No fumigants are registered for mountain beaver control. The use of smoke bombs or similar material is effective in locating the numerous openings in a mountain beaver burrow system.

Trapping

Mountain beavers are routinely kill trapped for damage control on many forest lands scheduled for planting. Trapping is usually done just prior to planting and repeated 1 or 2 years afterward. Trapping is also repeated when damage is found in established plantations. Set kill traps in older stands where stems and roots are being girdled and undermined. Live trapping is seldom done in forest lands except for research purposes, but it is used where there are urban damage problems.

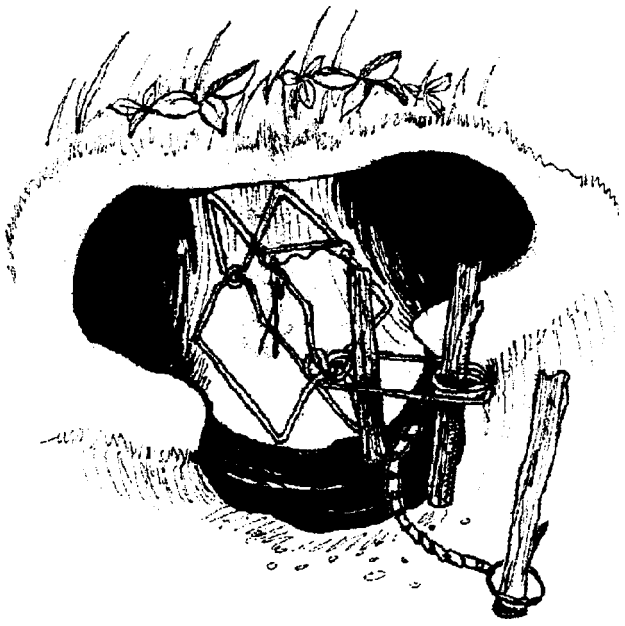

Fig. 10. Method for setting a kill trap in a mountain beaver burrow.

Kill trapping is normally done using unbaited Conibear® No. 110 traps set in main burrows. Anchor traps with three sticks, with either two in the spring (Fig. 10) or with one in the spring and one at the far end of the jaws, in a vertical position with the trigger hanging. The trap should take up most of the space in the burrow, and when properly anchored, is readily entered by the mountain beavers. This trap is sometimes not immediately lethal because of the mountain beaver's thick short neck. Stronger double-spring traps may be more effective, but are more difficult to set in the limited burrow space.

Teams of trappers are normally used when trapping large acreages. Individual trappers should be spaced about 30 to 50 feet (9.1 to 15.2 m) apart, depending on habitat conditions. Extra searching may be required in areas with many small drainages that may have many burrows. Active burrows have fresh soil and vegetation piled at burrow entrances or in burrows. Burrows can often be visually inspected through openings to determine if there is recent use. Set two or three traps in each active burrow system. All trap sites should be marked with flags and mapped so they may be relocated; a crew of trappers should use several colors of flagging so that individuals can relocate their own traplines by color. Trapping in older stands of conifers can be very difficult because traps are not easily relocated when branches hide the flagging. Mapping and flagging travel routes in this type of habitat may be necessary. The trap lines are usually checked after 1 day and again checked and pulled after about 5 days. Traps are usually reset during the first check even where mountain beavers are captured, because the systems may be quickly invaded by other mountain beavers. If trapping is unsuccessful, move traps to burrows with fresh activity. During the breeding season (January to March), male mountain beavers may be more commonly trapped than females because of their greater activity.

During subfreezing temperatures, trapping should be postponed or trapping periods lengthened to include warmer periods when mountain beavers are more active. Trapping during periods of snow is also usually less successful than during snow-free periods because trap sites are difficult to

locate and set, and animals are less active.

Trapping may take nontarget species such as weasels, spotted skunks (*Spilogale putorius*), mink, squirrels (*Tamiasciurus* spp.), rabbits, and hares that use the mountain beaver burrows. Nontarget losses may be reduced by positioning the trap trigger near the side of the trap so that it is less likely to be tripped when small animals pass through.

Live trapping is recommended where domestic animals may enter the burrows. Double-door wire mesh live traps such as Tomahawk traps (6 x 6 x 24 inches [15 x 15 x 61 cm]) should be set nearly level in main burrows. Suitable vegetation should be placed inside and along the outside of the trap. Wrap the trap with black plastic and cover it with soil to protect animals from the weather. Placement should assure that animals enter rather than go around the ends of the trap. Traps must be checked once or twice daily, preferably in early morning and again in the late afternoon, to minimize injury and stress to mountain beavers held in the live traps. Live-captured mountain beavers should be placed in dry burlap sacks and, if necessary, euthanized with carbon dioxide.

Shooting

Shooting is not a practical control method.

Other Methods

Habitat manipulation by increasing or decreasing favored vegetation has been evaluated only indirectly. Where native forbs were seeded to reduce deer damage to Douglas-fir plantations, mountain beaver damage did not significantly decrease or increase. In another area, where red huckleberry was abundant and extensively cut, mountain beaver damage to Douglas-fir was insignificant.

Economics of Damage and Control

Mountain beavers cause considerable economic damage to reforestation. Most of their habitat is in timberland where the potential crop value is high. Well-stocked stands of Douglas-fir are usually commercially thinned once or twice before final harvest, and often produce timber values of thousands of dollars per acre. When mountain beavers prevent reforestation or cause expenditures for protecting reforestation, the value of the crops is reduced or eliminated. A planned Douglas-fir crop rotation period of 40 years on good sites can be severely disrupted if at 15 years the crop is lost to damage by mountain beavers. Since mountain beaver damage occurs on about 300,000 acres (120,000 ha) of commercial forest land, a conservative annual loss estimate of $100 per acre ($250/ha) results in an annual loss of $30 million. Losses to mountain beavers may be $10,000 per acre ($24,700/ha) when damage causes failure of the timber crop.

Economic losses are caused by both direct and indirect damage. Cutting of planted tree seedlings is the most common damage. If it has been several years since planting, the site may need brush control by machine, hand, or herbicide before replanting can be done. Damage to tree seedlings also keeps the trees within a size range that is susceptible to damage by hares, rabbits, deer, and elk. If damage is not controlled, large areas may not be adequately reforested. Trees that escape early damage may be damaged later by girdling and undermining by mountain beavers, causing a loss of many years' growth of commercially valuable species.

The mountain beaver currently has no commercial value. The pelt has no fur value and there is no market for the meat. The animal is of significant zoological and medical interest, however, because of its limited range and unique physiological characteristics. Despite its limited range, however, the overall populations of mountain beavers have probably increased since timber harvesting began in the Pacific Northwest.

The burrowing and vegetation cutting activities of mountain beavers may improve soils and reduce competition by brush species. Sometimes, however, the burrowing activity has caused damage to roads and trails. Forest workers are periodically injured by falling into mountain beaver burrows.

An economic study of Pacific Northwest forest animal damage indicates that damage control expenditures of about $150 per acre ($375/ha) are reasonable on average-site Douglas-fir forest land. On higher quality land the expenditure for damage control can be higher, particularly where mountain beavers cause heavy mortality in reforestation areas.

Acknowledgments

I wish to thank numerous employees of USDA-APHIS, the USDA Forest Service, the USDI Bureau of Land Management, the Washington Department of Natural Resources, the Oregon Department of Forestry, and many private forest industry companies for support of studies involving research into mountain beaver damage control. I also wish to thank Kathryn Campbell for the illustrations drawn from photos and descriptions by the author.

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

James E. Miller
Program Leader, Fish and Wildlife
USDA Extension Service
Natural Resources and Rural
Development Unit
Washington, DC 20250

MUSKRATS

Fig. 1. Muskrat, *Ondatra zibethicus*

Damage Prevention and Control Methods

Exclusion

Riprap the inside of a pond dam face with rock, or slightly overbuild the dam to certain specifications.

Cultural Methods and Habitat Modification

Eliminate aquatic vegetation as a food source.

Draw down farm ponds during the winter months.

Frightening

Seldom effective in controlling serious damage problems.

Repellents

None are registered.

Toxicants

Zinc phosphide.

Anticoagulants (state registrations only).

Trapping

Body-gripping traps (Conibear® No. 110 and others).

Leghold traps, No. 1, 1 1/2, or 2.

Where legal, homemade "stove pipe" traps also are effective when properly used.

Shooting

Effective in eliminating some individuals.

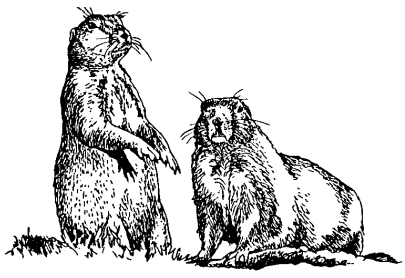
Other Methods

Integrated pest management.

Identification

The muskrat (*Ondatra zibethicus,* Fig. 1) is the largest microtine rodent in the United States. It spends its life in aquatic habitats and is well adapted for swimming. Its large hind feet are partially webbed, stiff hairs align the toes (Fig. 2), and its laterally flattened tail is almost as long as its body. The muskrat has a stocky appearance, with small eyes and very short, rounded ears. Its front feet, which are much smaller than its hind feet, are adapted primarily for digging and feeding.

The overall length of adult muskrats is usually from 18 to 24 inches (46 to 61 cm). Large males, however, will sometimes be more than 30 inches (76 cm) long, 10 to 12 inches (25 to 31 cm) of which is the laterally flattened tail. The average weight of adult muskrats is



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

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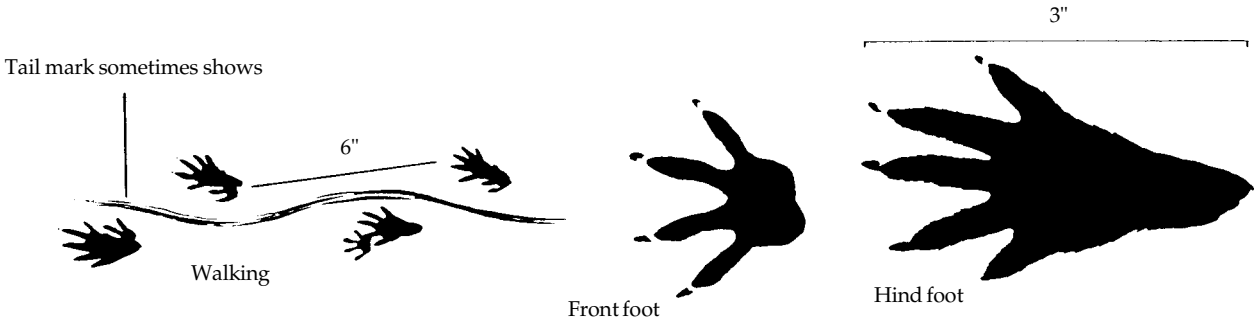


Fig. 2. Muskrat tracks

from 1 1/2 pounds (0.7 kg) to over 4 pounds (1.8 kg), with most at about 2 1/2 pounds (1.1 kg). The color of the belly fur is generally light gray to silver to tan, and the remaining fur varies from dark tan to reddish brown, dark brown, and black.

The name *muskrat*, common throughout the animal's range, derives from the paired perineal musk glands found beneath the skin at the ventral base of the tail in both sexes. These musk glands are used during the breeding season. Musk is secreted on logs or other defecation areas, around houses, bank dens, and trails on the bank to mark the area.

The muskrat has an upper and a lower pair of large, unrooted incisor teeth that are continually sharpened against each other and are well designed for gnawing and cutting vegetation. It has a valvular mouth, which allows the lips to close behind the incisors and enables the muskrat to gnaw while submerged. With its tail used as a rudder and its partially webbed hind feet propelling it in the water, the muskrat can swim up to slightly faster than 3 miles per hour (4.8 kph). When feeding, the muskrat often swims backward to move to a more choice spot and can stay underwater for as long as 20 minutes. Muskrat activity is predominantly nocturnal and crespuscular, but occasional activity may be observed during the day.

Muskrats in the wild have been known to live as long as 4 years, although most do not reach this age. In good habitat and with little competition, muskrats are very prolific. With a gestation period of between 25 and 30 days, females in the southern part of the range commonly produce 5 to 6 litters per year.

Range

The range of the muskrat extends from near the Arctic Circle in the Yukon and the Northwest Territories, down to the Gulf of Mexico, and from the Aleutians east to Labrador and down the Atlantic coast into Georgia (Fig. 3). The muskrat has been introduced practically all over the world, and, like most exotics, has sometimes caused severe damage as well as ecological problems. Muskrats often cause problems with ponds, levees, and crop culture, whether introduced or native. Muskrats are found in most aquatic habitats throughout the United States and Canada in streams, ponds, wetlands, swamps, drainage ditches, and lakes.

Fig. 3. Range of the muskrat in North America.

Habitat

Muskrats can live almost any place where water and food are available year-round. This includes streams, ponds, lakes, marshes, canals, roadside ditches, swamps, beaver ponds, mine pits, and other wetland areas. In shallow water areas with plentiful vegetation, they use plant materials to construct houses, generally conical in shape (Fig. 4). Elsewhere, they prefer bank dens, and in many habitats, they construct both bank dens and houses of vegetation. Both the houses of vegetation and the bank burrows or dens have several underwater entrances via "runs" or trails. Muskrats often have feeding houses, platforms, and chambers that are somewhat smaller than houses used for dens.

Burrowing activity is the source of the greatest damage caused by muskrats in much of the United States. They damage pond dams, floating styrofoam marinas, docks and boathouses, and lake shorelines. In states where rice and aquaculture operations are big business, muskrats can cause extensive economic losses. They damage rice culture by burrowing through or into levees as well as by eating substantial amounts of rice and cutting it down for building houses. In waterfowl marshes, population irruptions can cause "eat-out" where aquatic

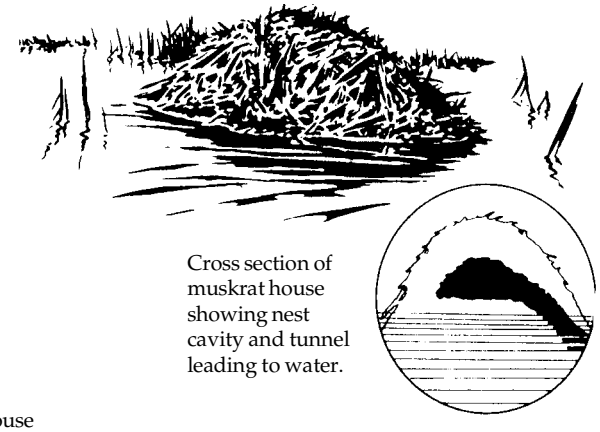


Fig. 4. Muskrat house

vegetation in large areas is virtually eliminated by muskrats. In some locations, such as in the rice-growing areas of Arkansas, muskrats move from overwintering habitat in canals, drainage ditches, reservoirs, and streams to make their summer homes nearby in flooded rice fields. In aquaculture reservoirs, damage is primarily to levees or pond banks, caused by burrowing.

Food Habits

Muskrats are primarily herbivores. They will eat almost any aquatic vegetation as well as some field crops grown adjacent to suitable habitat. Some of the preferred natural foods include cattail, pickerelweed, bulrush, smartweed, duck potato, horsetail, water lily, sedges, young willow regeneration, and other aquatics. Crops that are occasionally damaged include corn, soybeans, wheat, oats, grain sorghum, and sugarcane. Rice grown as a flooded crop is a common muskrat food. It is not uncommon, however, to see muskrats subsisting primarily on upland vegetation such as bermuda grass, clover, johnsongrass, and orchard grass where planted or growing on or around farm pond dams.

Although primarily herbivores, muskrats will also feed on crayfish, mussels, turtles, frogs, and fish in ponds where vegetation is scarce. In some aquaculture industry areas, this feeding habit should be studied, as it may differ significantly from normal feeding activity and can cause economic loss.

General Biology, Reproduction, and Behavior

Muskrats generally have a small home range but are rather territorial, and during breeding seasons some dispersals are common. The apparent intent of those leaving their range is to establish new breeding territories. Dispersal of males, along with young that are just reaching sexual maturity, seems to begin in the spring. Dispersal is also associated with population densities and population cycles. These population cycles vary from 5 years in some parts of North America to 10 years in others. Population levels can be impacted by food availability and accessibility.

Both male and female muskrats become more aggressive during the breeding season to defend their territories. Copulation usually takes place while submerged. The young generally are born between 25 and 30 days later in a house or bank den, where they are cared for chiefly by the female. In the southern states, some females may have as many as 6 litters per year. Litters may contain as many as 15, but generally average between 4 and 8 young. It has been reported that 2 to 3 litters per female per year is average in the Great Plains. This capability affords the potential for a prolific production of young. Young may be produced any month of the year. In Arkansas, the peak breeding periods are during November and March. Most of the young, however, are produced from October until April. Some are produced in the summer and early fall months, but not as many as in winter months. The period of highest productivity reported for the Great Plains is late April through early May. In the northern parts of its range, usually only 2 litters per year are produced between March and September.

Young muskrats are especially vulnerable to predation by owls, hawks, raccoons, mink, foxes, coyotes, and — in the southern states — even largemouth bass and snapping turtles. The young are also occasionally killed by adult muskrats. Adult muskrats may also be subject to predation, but rarely in numbers that would significantly alter populations. Predation cannot be depended upon to solve damage problems caused by muskrats.

Muskrats are hosts to large numbers of endo- and ectoparasites and serve as carriers for a number of diseases, including tularemia, hemorrhagic diseases, leptospirosis, ringworm disease, and pseudotuberculosis. Most common ectoparasites are mites and ticks. Endoparasites are predominantly trematodes, nematodes, and cestodes.

Damage and Damage Identification

Damage caused by muskrats is primarily due to their burrowing activity. Burrowing may not be readily evident until serious damage has occurred. One way to observe early burrowing in farm ponds or reservoirs is to walk along the edge of the dam or shorelines when the water is clear and look for “runs” or trails from just below the normal water surface to as deep as 3 feet (91 cm). If no burrow entrances are observed, look for droppings along the bank or on logs or structures a muskrat can easily climb upon. If the pond can be drawn down from 1 1/2 to 3 feet (46 to 91 cm) each winter, muskrat burrows will be exposed, just as they would during extended drought periods. Any burrows found in the dam should be filled, tamped in, and covered with rock to avoid possible washout or, if livestock are using

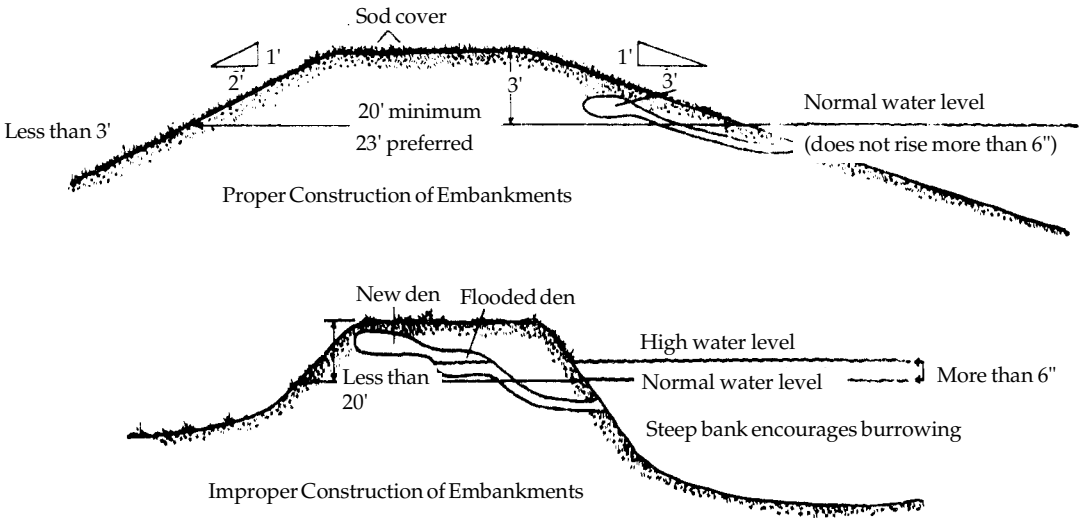


Fig. 5. Proper dam construction can reduce muskrat damage to the structure.

the pond, to prevent injury to a foot or leg.

Where damage is occurring to a crop, plant cutting is generally evident. In aquaculture reservoirs generally maintained without lush aquatic vegetation, muskrat runs and burrows or remains of mussels, crayfish, or fish along with other muskrat signs (tracks or droppings) are generally easy to observe.

Legal Status

Muskrats nationwide for many years were known as the most valuable furbearing mammal — not in price per pelt, but in total numbers taken. Each state fish and wildlife agency has rules and regulations regarding the taking of muskrats. Where the animal causes significant economic losses, some states allow the landowner to trap and/or use toxic baits throughout the year. Other states prohibit taking muskrats by any means except during the trapping season. Check existing state wildlife regulations annually before attempting to remove muskrats.

Damage Prevention and Control Methods

Exclusion

Muskrats in some situations can be excluded or prevented from digging into farm pond dams through stone rip-rapping of the dam. Serious damage often can be prevented, if anticipated, by constructing dams to the following specifications: the inside face of the dam should be built at a 3 to 1 slope; the outer face of the dam at a 2 to 1 slope with a top width of not less than 8 feet (2.4 m), preferably 10 to 12 feet (3 to 3.6 m). The normal water level in the pond should be at least 3 feet (91 cm) below the top of the dam and the spillway should be wide enough that heavy rainfalls will not increase the level of the water for any length of time (Fig. 5). These specifications are often referred to as overbuilding, but they will generally prevent serious damage from burrowing muskrats. Other methods of exclusion can include the use of fencing in certain situations where muskrats may be leaving a pond or lake to cut valuable garden plants or crops.

Cultural Methods and Habitat Modification

The best ways to modify habitat are to eliminate aquatic or other suitable foods eaten by muskrats, and where possible, to construct farm pond dams to previously suggested specifications. If farm pond dams or levees are being damaged, one of the ways that damage can be reduced is to draw the pond down at least 2 feet (61 cm) below normal levels during the winter. Then fill dens, burrows, and runs and rip-rap the dam with stone. Once the water is drawn down, trap or otherwise remove all muskrats.

Frightening Devices

Gunfire will frighten muskrats, especially those that get hit, but it is not effective in scaring the animals away from occupied habitat. No conventional frightening devices are effective.

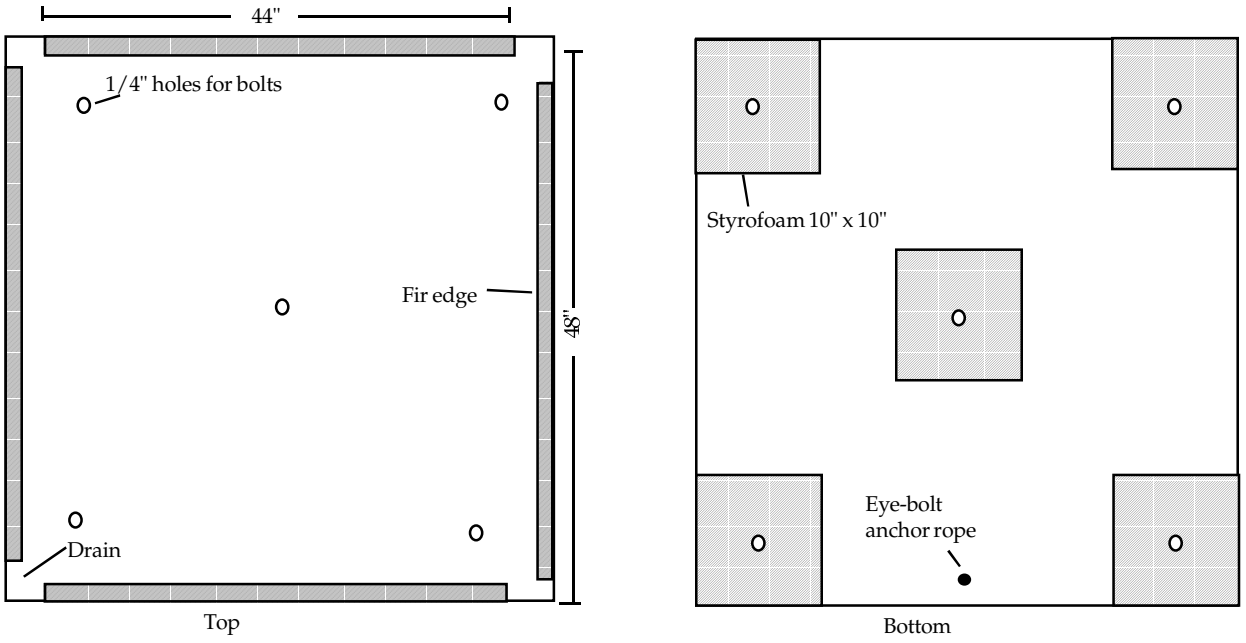
Repellents

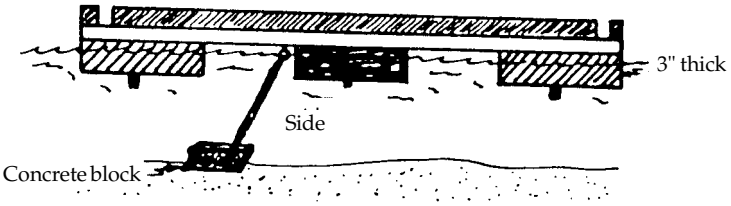
No repellents currently are registered for muskrats, and none are known to be effective, practical, and environmentally safe.

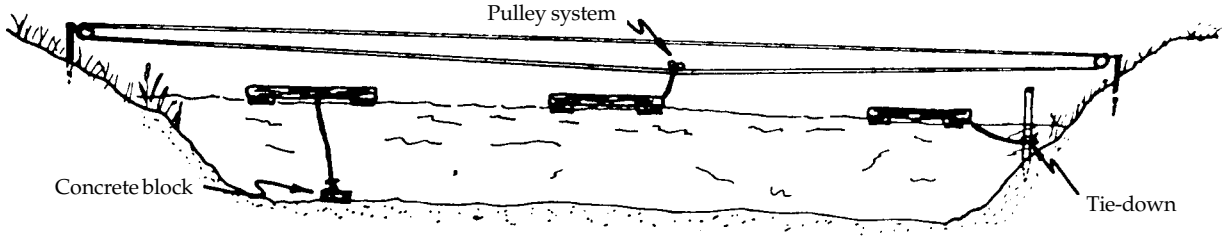
Toxicants

The only toxicant federally registered for muskrat control is zinc phosphide at 63% concentrate. It is a Restricted Use Pesticide for making baits. Zinc phosphide baits for muskrats generally are made by applying a vegetable oil sticker to cubes of apples, sweet potatoes, or carrots; sprinkling on the toxicant; and mixing thoroughly. The bait is then placed on floating platforms (Fig. 6), in burrow entrances, or on feeding houses. Use caution when mixing and applying baits treated with zinc phosphide. Carefully follow instructions on the zinc phosphide container before using.

Some states have obtained state registrations for use of anticoagulant baits







Rafts can be anchored in three ways.

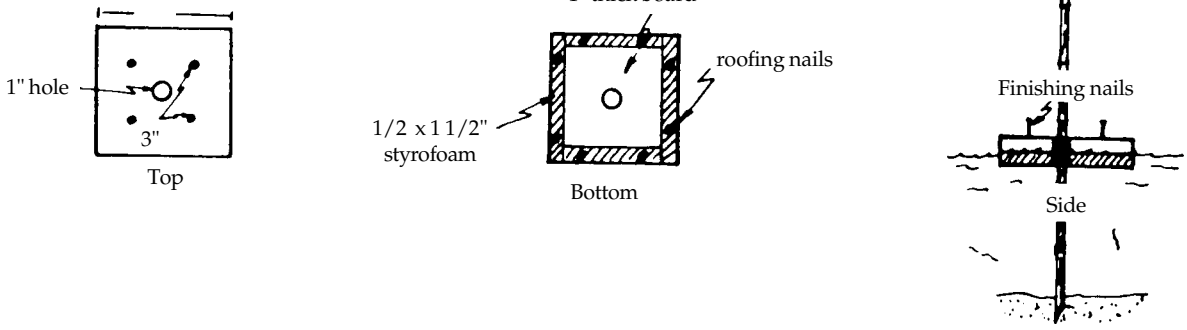


Fig. 6. A bait platform for controlling muskrats.

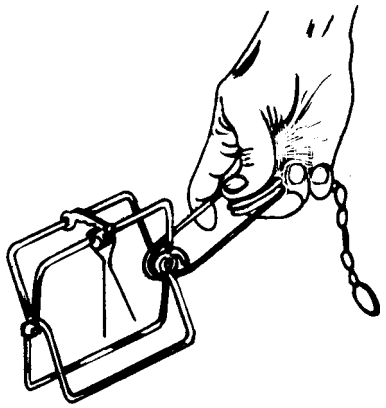


Fig. 7. Conibear®-type body-gripping kill trap

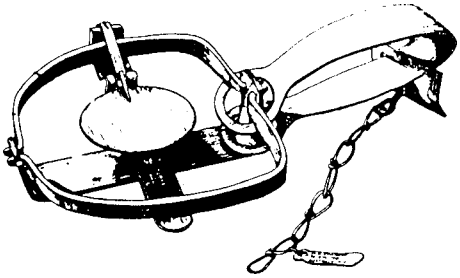


Fig. 8. Leghold trap

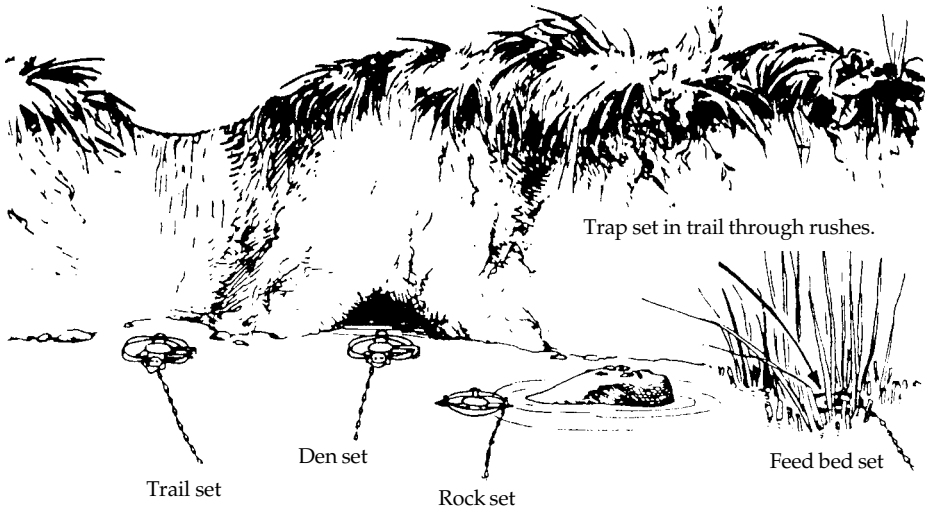


Fig. 9. Four sets for muskrats. Note: All traps are set under water. Chains are wired to anchors in deep water.

such as pivalyl, warfarin, diphacinone, and chlorophacinone. These materials have proven effective, species selective, practical, and environmentally safe in field applications to control muskrats. Apparently there is not sufficient demand or research available to consider federal registration of anticoagulants for muskrats. These same first-generation anticoagulants are, however, federally registered for use in control of commensal rodents in and around buildings, and for some use in field situations for rodent control.

Use of the anticoagulant baits, where registered, is in the form of a paraffinized "lollipop" made of grain, pesticide, and melted paraffin. It is placed in burrows or feeding houses. The anticoagulant baits also can be used as a grain mixture in floating bait boxes.

Fumigants

No fumigants are currently registered for muskrat control.

Trapping

There have probably been more traps sold for catching muskrats than for catching any other furbearing species. A number of innovative traps have been constructed for both live trapping and killing muskrats, such as barrel, box, and stovepipe traps.

The most effective and commonly used types of traps for muskrats, however, are the Conibear®-type No. 110 (Fig. 7) and leghold types such as the long spring No. 1, 1 1/2, or 2 (Fig. 8) and comparable coil spring traps. Each type has places and situations where one might be more effective than another. The Conibear®-type, No. 110 is a preferred choice because it is as effective in 6 inches (15 cm) of water as at any deeper level. It kills the muskrat almost instantly, thus preventing escapes. All that is needed to make this set is a trap stake and trap.

Muskrats are probably the easiest aquatic furbearer to trap. In most cases where the run or burrow entrance is in 2 feet (61 cm) of water or more, even a leghold trap requires only a forked

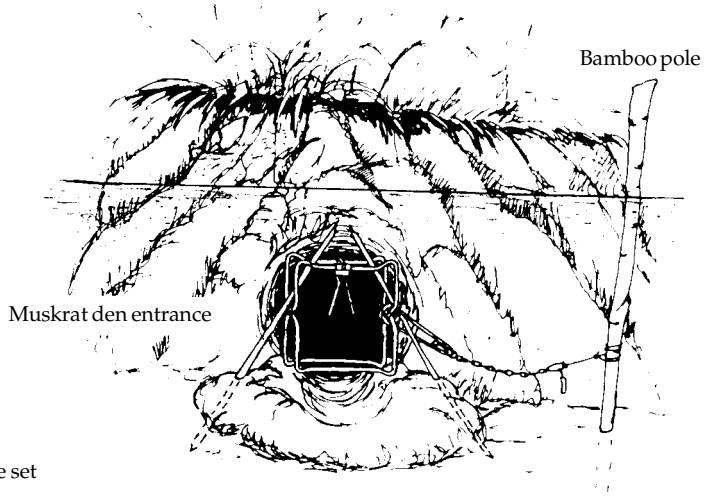
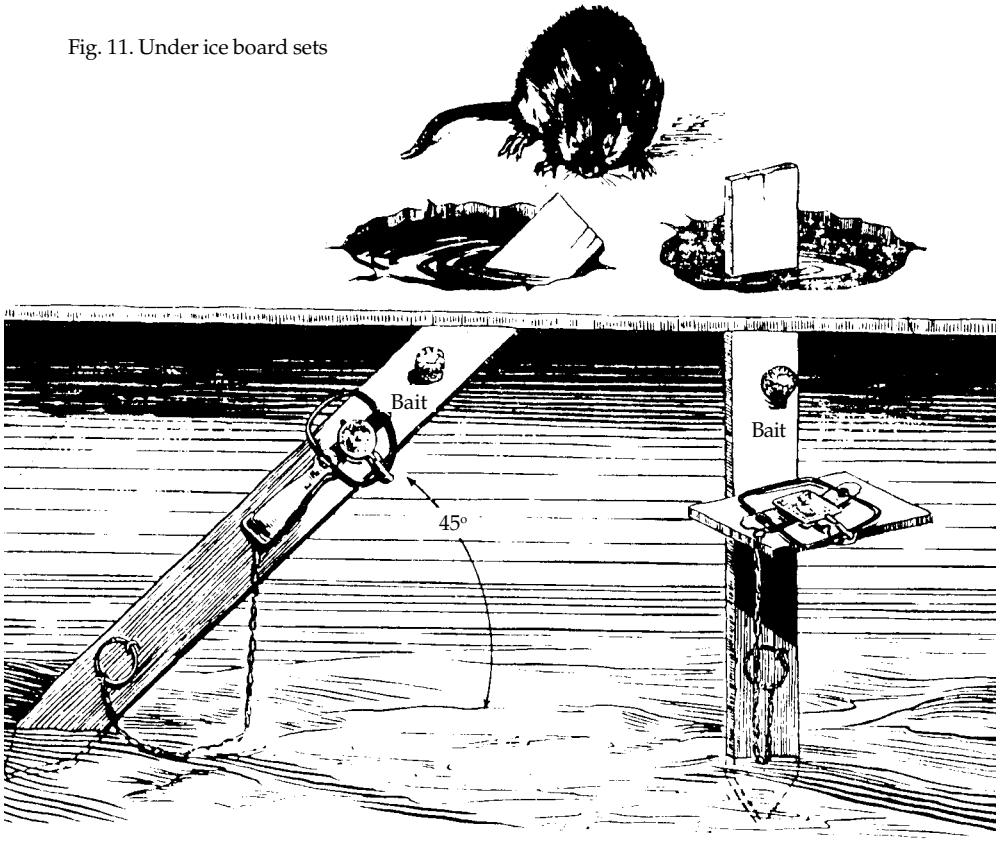


Fig. 10. Pole set

Fig. 11. Under ice board sets



stake to make a drowning set. A trap set in the run, the house or den entrance, or even under a feeding house, will usually catch a muskrat in 1 or 2 nights. As a test of trap efficiency, this author once set 36 Conibear®-type No. 110 traps in a 100-acre (40-ha) rice field and 24 No. 1 1/2 leghold traps in a nearby 60-acre (24-ha) minnow pond on a July day. The next day 55 muskrats were removed. The remaining traps had not been tripped. Obviously, both of these areas held high populations of muskrats and neither had been subjected to recent control efforts. Results were 93.3% effectiveness with the Conibear®-type, 87.5% effectiveness with the leghold traps, and 100% catch per traps tripped.

The most effective sets are those placed in "runs" or trails where the muskrat's hind feet scour out a path into the bottom from repeated trips into and out of the den. These runs or trails can be seen in clear water, or can be felt underwater with hands or feet. Which runs are being used and which are alternate entrances can usually be discerned by the compaction of the bottom of the run. Place the trap as close to the den entrance as possible without restricting trap movement (Fig. 9).

Other productive sets are pole sets, under ice sets (Figs. 10 and 11), and culvert sets. Other traps also can be used effectively in some situations.

The stovepipe trap (Fig. 12) is very effective in farm ponds, rice fields, and marshes — where it is legal. This type of trap requires more time and effort to set, but can be very effective if the correct size is used. The trap is cheap,

Note: A length of 5-inch-diameter stovepipe can be substituted for the side and bottom boards. In this case, the hinged doors must be made U-shaped.

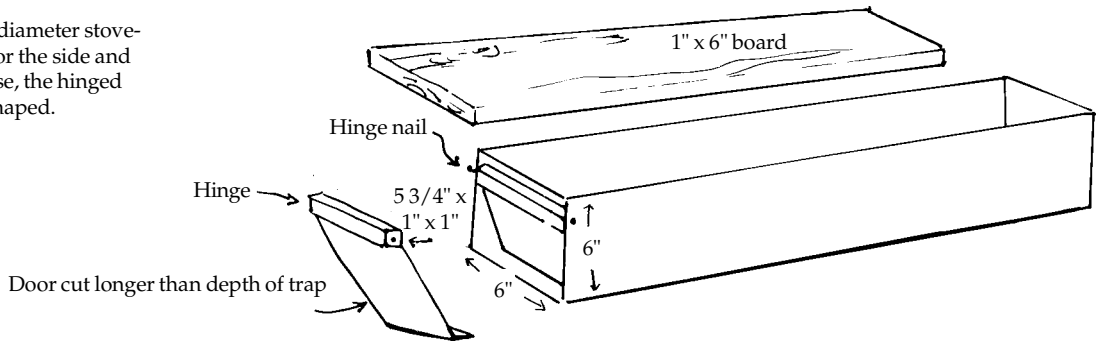


Fig. 12. Stovepipe trap

simple, and easy to make; however, to my knowledge, it is not available commercially. If properly set in a well-used den entrance, it will make multiple catches.

The stovepipe trap has the potential to catch from two to four muskrats on the first night if set in the primary den entrance. The trap is cumbersome to carry around, however, and must be staked down properly and set right up against the den entrance to be most effective. The traps can be easily made from stovepipe, as the name implies, but some of the most effective versions are variations. An example is a sheet metal, 6 x 6-inch (15 x 15-cm) rectangular box, 30 to 36 inches (76 to 91 cm) long with heavy-gauge hardware cloth or welded wire doors. The doors are hinged at the top to allow easy entry from either end, but no escape out of the box. Death from drowning occurs in a short time. The trap design also allows for multiple catches. Its flat bottom works well on most pond bottoms and in flooded fields or marshes, and it is easy to keep staked down in place. Such a trap can be made in most farm shops in a few minutes. All sets should be checked daily.

Trapping muskrats during the winter furbearer season can be an enjoyable past-time and even profitable where prices for pelts range from $2.00 to $8.00 each. Price differences depend on whether pelts are sold "in the round" or skinned and stretched. Many people supplement their income by trapping, and muskrats are one of the prime targets for most beginners learning to trap. Therefore, unless muskrats are causing serious damage, they should be managed like other wildlife species to provide a sustained annual yield. Unfortunately, when fur prices for muskrats are down to less than $2.00 each, interest in trapping for fur seems to decline. However, in damage situations, it may be feasible to supplement fur prices to keep populations in check.

Shooting

Where it can be done safely, shooting may eliminate one or two individuals in a small farm pond. Concentrated efforts must be made at dusk and during the first hours of light in the early morning. Muskrats shot in the water rarely can be saved for the pelt and/or meat.

Other Methods

Although a variety of other methods are often employed in trying to control muskrat damage, a combination of trapping and proper use of toxicants is the most effective means in most situations. In situations where more extensive damage is occurring, it may be useful to employ an integrated pest management approach: (1) modify the habitat by removing available food (vegetation); (2) concentrate efforts to reduce the breeding population during winter months while muskrats are concentrated in overwintering habitat; and (3) use both registered toxicants and trapping in combination with the above methods.

There may be other effective methods beyond those already discussed. Some may not be species selective or environmentally safe. Before using any control methods for wildlife damage prevention or control, check existing regulations and use tools and methods that do not pose a danger to nontarget species.

Economics of Damage and Control

Assessment of the amount of damage being caused and the cost of prevention and control measures should be made before undertaking a control program. Sometimes this can be easily done by the landowner or manager through visual inspection and knowledge of crop value or potential loss and reconstruction or replacement costs. Other situations are more difficult to assess. For example, what is the economic value of frustration and loss of a truckload of minnows and/or fish after a truck has fallen through the levee into burrowed-out muskrat dens? Or how do you evaluate the loss of a farm pond dam or levee and water behind it from an aquaculture operation where hundreds of thousands of pounds of fish are being grown? Rice farmers in the mid-South or in California must often pump extra, costly irrigation water and shovel levees every day because of muskrat damage. The expense of trapping or other control measures may prove cost-effective if damage is anticipated.

Obviously, the assessments are different in each case. The estimate of economic loss and repair costs, for example, for rebuilding levees, replacing drain pipes, and other measures, must be compared to the estimated cost of prevention and/or control efforts.

Economic loss to muskrat damage can be very high in some areas, particularly in rice and aquaculture producing areas. In some states damage may be as much as $1 million per year. Totals in four states (Arkansas, California, Louisiana, and Mississippi) exceed losses throughout the rest of the nation.

Elsewhere, economic losses because of muskrat damage may be rather limited and confined primarily to burrowing in farm pond dams. In such limited cases, the value of the muskrat population may outweigh the cost of the damage.

Muskrat meat has been commonly used for human consumption and in some areas called by names, such as "marsh rabbit." A valuable resource, it is delicious when properly taken care of in the field and in the kitchen. Many wild game or outdoor cookbooks have one or more recipes devoted to "marsh rabbit." Care should be taken in cleaning muskrats because of diseases mentioned earlier.

Muskrat pelts processed annually are valued in the millions of dollars, even with low prices; thus the animal is certainly worthy of management consideration. It obviously has other values just by its place in the food chain.

Acknowledgments

Most of the information in this chapter was obtained from experience gained in Alabama, where as a youngster I trapped muskrats and other furbearers to sell, and in Arkansas where muskrat control is a serious economic problem. Colleagues in the Arkansas Cooperative Extension Service, and especially county extension agents, provided the opportunity and background for obtaining this information. The Arkansas Farm Bureau, many rice farmers, fish farmers, and other private landowners/managers, as well as the Arkansas Game and Fish Commission and the Arkansas State Plant Board, were also important to the development of this information.

Figures 1 through 4 from Schwartz and Schwartz (1981).

Figure 5 from Henderson (1980).

Figure 6 from J. Evans (1970), *About Nutria and their Control*, USDI, Bureau of Sport Fisheries and Wildlife, Resour. Pub. No. 86. 65 pp.

Figures 7 and 8 from Miller (1976).

Figures 9, 10, and 11 from Manitoba Trapper Education publications.

Figure 12 by Jill Sack Johnson.

For Additional Information

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Dwight J. LeBlanc
State Director
USDA-APHIS-
Animal Damage Control
Port Allen, Louisiana 70767

NUTRIA

Fig. 1. Nutria (*Myocastor coypus*)

Damage Prevention and Control Methods

Exclusion

Protect small areas with partially buried fences.

Wire tubes can be used to protect baldcypress or other seedlings but are expensive and difficult to use.

Use sheet metal shields to prevent gnawing on wooden and styrofoam structures and trees near aquatic habitat.

Install bulkheads to deter burrowing into banks.

Cultural Methods and Habitat Modification

Improve drainage to destroy travel lanes.

Manage vegetation to eliminate food and cover.

Contour stream banks to control burrowing.

Plant baldcypress seedlings in the fall to minimize losses.

Restrict farming, building construction, and other "high risk" activities to upland sites away from water to prevent damage.

Manipulate water levels to stress nutria populations.

Frightening

Ineffective.

Repellents

None are registered. None are effective.

Toxicants

Zinc phosphide on carrot or sweet potato baits.

Fumigants

None are registered. None are effective.

Trapping

Commercial harvest by trappers.

Double longspring traps, Nos. 11 and 2, as preferred by trappers and wildlife damage control specialists.

Body-gripping traps, for example, Conibear® Nos. 160-2 and 220-2, and locking snares are most effective when set in trails, den entrances, or culverts.

Live traps should be used when leghold and body-gripping traps cannot be set.

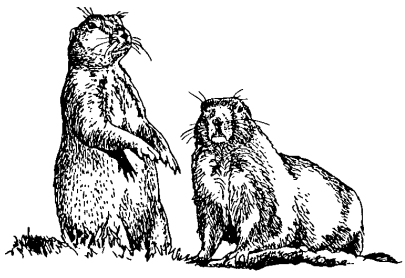
Long-handled dip nets can be used to catch unwary nutria.

Shooting

Effective when environmental conditions force nutria into the open. Night hunting is illegal in many states.

Other Methods

Available control techniques may not be applicable to all damage situations. In these cases, safe and effective methods must be tailored to specific problems.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

B-71

Identification

The nutria (*Myocastor coypus,* Fig. 1) is a large, dark-colored, semiaquatic rodent that is native to southern South America. At first glance, a casual observer may misidentify a nutria as either a beaver (*Castor canadensis*) or a muskrat (*Ondatra zibethicus*), especially when it is swimming. This superficial resemblance ends when a more detailed study of the animal is made. Other names used for the nutria include coypu, nutria-rat, South American beaver, Argentine beaver, and swamp beaver.

Nutria are members of the family Myocastoridae. They have short legs and a robust, highly arched body that is approximately 24 inches (61 cm) long. Their round tail is from 13 to 16 inches (33 to 41 cm) long and scantily haired. Males are slightly larger than females; the average weight for each is about 12 pounds (5.4 kg). Males and females may grow to 20 pounds (9.1 kg) and 18 pounds (8.2 kg), respectively.

The dense grayish underfur is overlaid by long, glossy guard hairs that vary in color from dark brown to yellowish brown. The forepaws have four well-developed and clawed toes and one vestigial toe. Four of the five clawed toes on the hind foot are interconnected by webbing; the fifth outer toe is free. The hind legs are much larger than the forelegs. When moving on land, a nutria may drag its chest and appear to hunch its back. Like beavers, nutria have large incisors that are yellow-orange to orange-red on their outer surfaces.

In addition to having webbed hind feet, nutria have several other adaptations to a semiaquatic life. The eyes, ears, and nostrils of nutria are set high on their heads. Additionally, the nostrils and mouth have valves that seal out water while swimming, diving, or feeding underwater. The mammae or teats of the female are located high on the sides, which allows the young to suckle while in the water. When pursued, nutria can swim long distances under water and see well enough to evade capture.

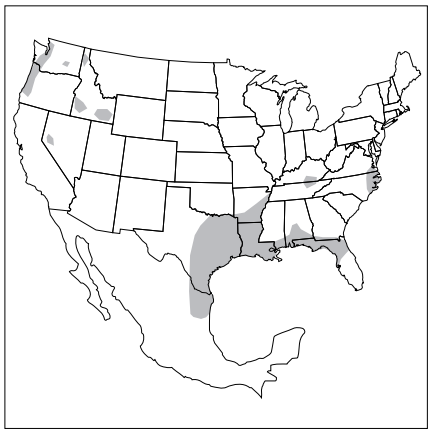


Fig. 2. Range of the nutria introduced in North America.

Range

The original range of nutria was south of the equator in temperate South America. This species has been introduced into other areas, primarily for fur farming, and feral populations can now be found in North America, Europe, the Soviet Union, the Middle East, Africa, and Japan. *M. c. bonariensis* was the primary subspecies of nutria introduced into the United States.

Fur ranchers, hoping to exploit new markets, imported nutria into California, Washington, Oregon, Michigan, New Mexico, Louisiana, Ohio, and Utah between 1899 and 1940. Many of the nutria from these ranches were freed into the wild when the businesses failed in the late 1940s. State and federal agencies and individuals translocated nutria into Alabama, Arkansas, Georgia, Kentucky, Maryland, Mississippi, Oklahoma, Louisiana, and Texas, with the intent that nutria would control undesirable vegetation and enhance trapping opportunities. Nutria were also sold as "weed cutters" to an ignorant public throughout the Southeast. A hurricane in the late 1940s aided dispersal by scattering nutria over wide areas of coastal southwest Louisiana and southeast Texas.

Accidental and intentional releases have led to the establishment of widespread and localized populations of nutria in various wetlands throughout the United States. Feral animals have been reported in at least 40 states and three Canadian provinces in North America since their introduction. About one-third of these states still have viable populations that are stable or increasing in number. Some of the populations are economically important to the fur industry. Adverse climatic conditions, particularly extreme cold, are probably the main factors limiting range expansion of nutria in North America. Nutria populations in the United States are most dense along the Gulf Coast of Louisiana and Texas (Fig. 2).

Habitat

Nutria adapt to a wide variety of environmental conditions and persist in areas previously claimed to be unsuitable. In the United States, farm ponds and other freshwater impoundments, drainage canals with spoil banks, rivers and bayous, freshwater and brackish marshes, swamps, and combinations of various wetland types can provide a home to nutria. Nutria habitat, in general, is the semiaquatic environment that occurs at the boundary between land and permanent water. This zone usually has an abundance of emergent aquatic vegetation, small trees, and/or shrubs and may be interspersed with small clumps and hillocks of high ground. In the United States, all significant nutria populations are in coastal areas, and freshwater marshes are the preferred habitat.

Food Habits

Nutria are almost entirely herbivorous and eat animal material (mostly insects) incidentally, when they feed on plants. Freshwater mussels and crustaceans are occasionally eaten in some parts of their range. Nutria are opportunistic feeders and eat approximately 25% of their body weight daily. They prefer several small meals to one large meal.

The succulent, basal portions of plants are preferred as food, but nutria also eat entire plants or several different parts of a plant. Roots, rhizomes, and tubers are especially important during winter. Important food plants in the

United States include cordgrasses (*Spartina* spp.), bulrushes (*Scirpus* spp.), spikerushes (*Eleocharis* spp.), chafflower (*Alternanthera* spp.), pickerelweeds (*Pontederia* spp.), cattails (*Typha* spp.), arrowheads (*Sagittaria* spp.), and flatsedges (*Cyperus* spp.). During winter, the bark of trees such as black willow (*Salix nigra*) and baldcypress (*Taxodium distichum*) may be eaten. Nutria also eat crops and lawn grasses found adjacent to aquatic habitat.

Because of their dexterous forepaws, nutria can excavate soil and handle very small food items. Food is eaten in the water; on feeding platforms constructed from cut vegetation; at floating stations supported by logs, decaying mats of vegetation, or other debris; in shallow water; or on land. In some areas, the tops of muskrat houses and beaver lodges may also be used as feeding platforms.

General Biology, Reproduction, and Behavior

General Biology

In the wild, most nutria probably live less than 3 years; captive animals, however, may live 15 to 20 years. Predation, disease and parasitism, water level fluctuations, habitat quality, highway traffic, and weather extremes affect mortality. Annual mortality of nutria is between 60% and 80%.

Predators of nutria include humans (through regulated harvest), alligators (*Alligator mississippiensis*), garfish (*Lepisosteus* spp.), bald eagles (*Haliaeetus leucocephalus*), and other birds of prey, turtles, snakes such as the cottonmouth (*Agkistrodon piscivorus*), and several carnivorous mammals.

Nutria densities vary greatly. In Louisiana, autumn densities of about 18 animals per acre (44/ha) have been found in floating freshwater marshes. In Oregon, summer densities in freshwater marshes may be 56 animals per acre (138/ha). Sex ratios range from 0.6 to 1.6 males per female.

In summer, nutria live on the ground in dense vegetation, but at other times of the year they use burrows. Burrows may be those abandoned by other animals such as armadillos (*Dasypus novemcinctus*), beavers, and muskrats, or they may be dug by nutria. Underground burrows are used by individuals or multigenerational family groups.

Burrow entrances are usually located in the vegetated banks of natural and human-made waterways, especially those having a slope greater than 45°. Burrows range from a simple, short tunnel with one entrance to complex systems with several tunnels and entrances at different levels. Tunnels are usually 4 to 6 feet (1.2 to 1.8 m) long; however, lengths of up to 150 feet (46 m) have been recorded. Compartments within the tunnel system are used for resting, feeding, escape from predators and the weather, and other activities. These vary in size, from small ledges that are only 1 foot (0.3 m) across to large family chambers that measure 3 feet (0.9 m) across. The floors of these chambers are above the water line and may be covered with plant debris discarded during feeding and shaped into crude nests.

In addition to using land nests and burrows, nutria often build flattened circular platforms of vegetation in shallow water. Constructed of coarse emergent vegetation, these platforms are used for feeding, loafing, grooming, birthing, and escape, and are often misidentified as muskrat houses. Initially, platforms may be relatively low and inconspicuous; however, as vegetation accumulates, some may attain a height of 3 feet (0.9 m).

Reproduction

Nutria breed in all seasons throughout most of their range, and sexually active individuals are present every month of the year. Reproductive peaks occur in late winter, early summer, and mid-autumn, and may be regulated by prevailing weather conditions.

Under optimal conditions, nutria reach sexual maturity at 4 months of age. Female nutria are polyestrous, and nonpregnant females cycle into estrus ("heat") every 2 to 4 weeks. Estrous is maintained for 1 to 4 days in most females. Sexually mature males can breed at any time because sperm is produced throughout the year.

The gestation period for nutria ranges from 130 to 132 days. A postpartum estrus occurs within 48 hours after birth and most females probably breed again during that time.

Litters average 4 to 5 young, with a range of 1 to 13. Litter sizes are generally smaller during winter, in suboptimal habitats, and for young females. Females often abort or assimilate embryos in response to adverse environmental conditions.

Young are precocial and are born fully furred and active. They weigh approximately 8 ounces (227 g) at birth and can swim and eat vegetation shortly thereafter. Young normally suckle for 7 to 8 weeks until they are weaned.

Behavior

Nutria tend to be crepuscular and nocturnal, with the start and end of activity periods coinciding with sunset and sunrise, respectively. Peak activity occurs near midnight. When food is abundant, nutria rest and groom during the day and feed at night. When food is limited, daytime feeding increases, especially in wetlands free from frequent disturbance.

Nutria generally occupy a small area throughout their lives. In Louisiana, the home range of nutria is about 32 acres (13 ha). Daily cruising distances for most nutria are less than 600 feet (183 m), although some individuals may travel much farther. Nutria move most in winter, due to an increased demand for food. Adults usually move farther than young. Seasonal migrations of nutria may also occur. Nutria living in some agricultural areas move in from marshes and swamps when crops are planted and leave after the crops are harvested.

Nutria have relatively poor eyesight and sense danger primarily by hearing. They occasionally test the air for scent. Although they appear to be

clumsy on land, they can move with surprising speed when disturbed. When frightened, nutria head for the nearest water, dive in with a splash, and either swim underwater to protective cover or stay submerged near the bottom for several minutes. When cornered or captured, nutria are aggressive and can inflict serious injury to pets and humans by biting and scratching.

Damage and Damage Identification

Kinds of Damage

Nutria damage has been observed throughout their range. Most damage is from feeding or burrowing. In the United States, most damage occurs along the Gulf Coast of Louisiana and Texas. The numerous natural and human-made waterways that traverse this area are used extensively for travel by nutria.

Burrowing is the most commonly reported damage caused by nutria. Nutria are notorious in Louisiana and Texas for undermining and breaking through water-retaining levees in flooded fields used to produce rice and crawfish. Additionally, nutria burrows sometimes weaken flood control levees that protect low-lying areas. In some cases, tunneling in these levees is so extensive that water will flow unobstructed from one side to the other, necessitating their complete reconstruction.

Nutria sometimes burrow into the styrofoam flotation under boat docks and wharves, causing these structures to lean and sink. They may burrow under buildings, which may lead to uneven settling or failure of the foundations. Burrows can weaken roadbeds, stream banks, dams, and dikes, which may collapse when the soil is saturated by rain or high water or when subjected to the weight of heavy objects on the surface (such as vehicles, farm machinery, or grazing livestock). Rain and wave action can wash out and enlarge collapsed burrows and compound the damage.

Nutria depredation on crops is well documented. In the United States, sugarcane and rice are the primary crops damaged by nutria. Grazing on rice plants can significantly reduce yields, and damage can be locally severe. Sugarcane stalks are often gnawed or cut during the growing season. Often only the basal internodes of cut plants are eaten. Other crops that have been damaged include corn, milo (grain sorghum), sugar and table beets, alfalfa, wheat, barley, oats, peanuts, various melons, and a variety of vegetables from home gardens and truck farms.

Nutria girdle fruit, nut, and shade trees and ornamental shrubs. They also dig up lawns and golf courses when feeding on the tender roots and shoots of sod grasses. Gnawing damage to wooden structures is common. Nutria also gnaw on styrofoam floats used to mark the location of traps in commercial crawfish ponds.

At high densities and under certain adverse environmental conditions, foraging nutria can significantly impact natural plant communities. In Louisiana, nutria often feed on seedling baldcypress and can cause the complete failure of planted or naturally-regenerated stands. Overutilization of emergent marsh plants can damage stands of desirable vegetation used by other wildlife species and aggravate coastal erosion problems by destroying vegetation that holds marsh soils together. Nutria are fond of grassy arrowhead (*Sagittaria platyphylla*) tubers and may destroy stands propagated as food for waterfowl in artificial impoundments.

Nutria can be infected with several pathogens and parasites that can be transmitted to humans, livestock, and pets. The role of nutria, however, in the spread of diseases such as equine encephalomyelitis, leptospirosis, hemorrhagic septicemia (Pasteurellosis), paratyphoid, and salmonellosis is not well documented. They may also host a number of parasites, including the nematodes and blood flukes that cause "swimmer's-itch" or "nutria-itch" (*Strongyloides myopotami* and *Schistosoma mansoni*), the protozoan responsible for giardiasis (*Giardia lamblia*), tapeworms (*Taenia* spp.), and common liver flukes (*Fasciola hepatica*). The threat of disease may be an important consideration in some situations, such as when livestock drink from water contaminated by nutria feces and urine.

Damage Identification

The ranges of nutria, beavers, and muskrats overlap in many areas and damage caused by each may be similar in appearance. Therefore, careful examination of sign left at the damage site is necessary to identify the responsible species.

On-site observations of animals and their burrows are the best indicators of the presence of nutria. Crawl outs, slides, trails, and the exposed entrances to burrows often have tracks that can be used to identify the species. The hind foot, which is about 5 inches (13 cm) long, has four webbed toes and a free outer toe. A drag mark left by the tail may be evident between the footprints (Fig. 3).

Droppings may be found floating in the water, along trails, or at feeding sites. These are dark green to almost black in color, cylindrical, and approximately 2 inches (5 cm) long and 1/2 inch (1.3 cm) in diameter. Additionally, each dropping usually has deep, parallel grooves along its entire length (Fig. 4).

Trees girdled by nutria often have no tooth marks, and bark may be peeled from the trunk. The crowns of seedling trees are usually clipped (similar to rabbit [*Sylvilagus* spp.] damage) and discarded along with other woody portions of the plant.

In rice fields, damage caused by nutria, muskrats, and Norway rats (*Rattus norvegicus*) can be confused. Nutria and muskrats damage rice plants by clipping stems at the water line in flooded fields; Norway rats reportedly clip stems above the surface of the water (E. A. Wilson, personal communication).

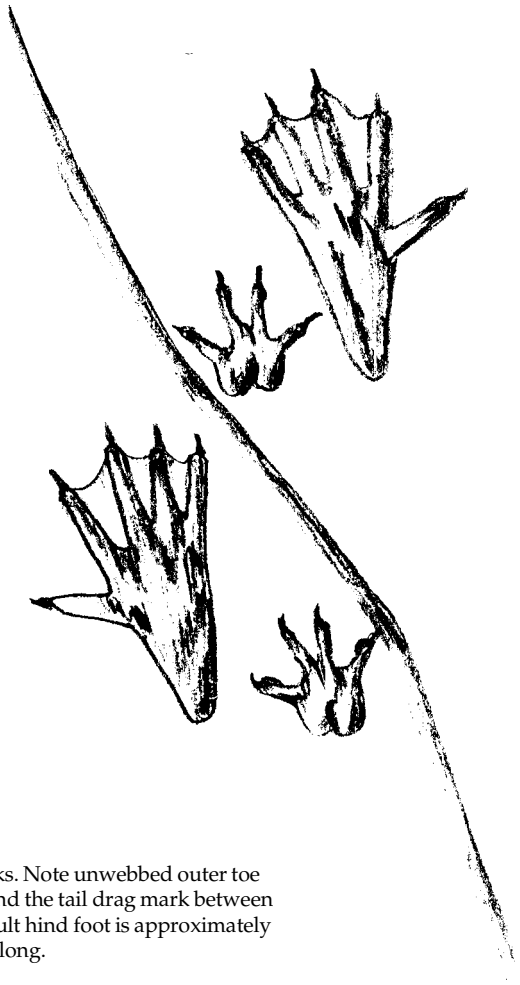


Fig. 3. Nutria tracks. Note unwebbed outer toe on the hind foot and the tail drag mark between the tracks. The adult hind foot is approximately 5 inches (12.7 cm) long.

Fig. 4. Nutria dropping in relation to a 2-inch (5.1-cm) camera lens cover. Note longitudinal grooves along the length of the dropping.

Legal Status

Nutria are protected as furbearers in some states or localities because they are economically important. Permits may be necessary to control animals that are damaging property. In other areas, nutria have no legal protection and can be taken at any time by any legal means. Consequently, citizens experiencing problems with nutria should be familiar with local wildlife laws and regulations. Complex problems should be handled by professional wildlife damage control specialists who have the necessary permits and expertise to do the job correctly. Your state wildlife agency can provide the names of qualified wildlife damage control specialists and information on pertinent laws and regulations.

Damage Prevention and Control Methods

Preventive measures should be used whenever possible, especially in areas where damage is prevalent. When control is warranted, all available techniques should be considered before a control plan is implemented. The objective of control is to use only those techniques that will stop or alleviate anticipated or ongoing damage or reduce it to tolerable levels. In most cases, successful control will depend on integrating a number of different techniques and methods.

Timing and location of control activities are important factors governing the success or failure of any control project. Control in sugarcane, for example, is best applied during the growing season, after damage has started. At this time, nutria in affected areas are relatively stationary and concentrated in drainages adjacent to fields. Conversely, efforts to protect rice field levees or the shorelines of southern lakes and ponds should be initiated during the winter when animals are mobile and concentrated in major ditches and other large bodies of water.

Nutria are best controlled where they are causing damage or where they are most active. Baiting is sometimes used to concentrate nutria in specific locations where they can be controlled more easily. After the main concentrations of nutria are removed, control efforts should be directed at removing wary individuals.

Exclusion

Fences, walls, and other structures can reduce nutria damage, but high costs usually limit their use. As a general rule, barriers are too expensive to be used to control damage to agricultural crops. Low fences (about 4 feet [1.2 m]) with an apron buried at least 6 inches (15 cm) have been used effectively to exclude nutria from home gardens and lawns. Sheet metal shields can be used to prevent gnawing damage to wooden and styrofoam structures and trees. Barriers constructed of sheet metal can be expensive to erect and unsightly.

Protect baldcypress and other seedlings with hardware cloth tubes around individual plants or wire mesh fencing around the perimeter of a stand. Extensive use of these is neither practical nor cost-effective. Plastic seedling protectors are not effective in controlling damage to baldcypress seedlings because nutria can chew through them.

Sheet piling, bulkheads, and riprap can effectively protect stream banks from burrowing nutria. Installation requires heavy equipment and is expensive. Use is usually restricted to industrial or commercial applications.

Cultural Methods and Habitat Modification

Land that is well-drained and free of dense, weedy vegetation is generally unattractive to nutria. Use of other good farming practices, such as precision land leveling and weed management, can minimize nutria damage in agricultural areas.

Draining and Grading. Any drainage that holds water can be used by nutria as a travel route or home site. Consequently, eliminate standing water in drainages to reduce their attractiveness to nutria. This may be extremely difficult or impossible to accomplish in low-lying areas near coastal marshes and permanent bodies of water. Higher sites, such as those used for growing sugarcane and other crops, are better suited for this type of management.

On poorly drained soils, contour small ditches to eliminate low spots and sills and enhance rapid drainage. Use precision leveling on well-drained soils to eliminate small ditches that are occasionally used by nutria.

Grading and bulldozing can destroy active burrows in the banks of steep-sided ditches and waterways. In addition, contour bank slopes at less than 45° to discourage new burrowing. Sculpting rice field levees to make them gently sloping is similarly effective. Continued deep plowing of land undermined by nutria can destroy shallow burrow systems and discourage new burrowing activity.

Vegetation Control. Eliminate brush, trees, thickets, and weeds from fence lines and turn rows that are adjacent to ditches, drainages, waterways, and other wetlands to discourage nutria. Burn or remove cleared vegetation from the site. Brush piles left on the ground or in low spots can become ideal summer homes for nutria.

Water Level Manipulation. Many low-lying areas along the Gulf Coast are protected by flood control levees and pumps that can be used to manipulate water levels. By dropping water levels during the summer, stressful drought conditions that cause nutria to concentrate in the remaining aquatic habitat can be simulated, thus increasing competition for food and space, exposure to predators, and emigration to other suitable habitat. Raising water levels in winter will force nutria out of their burrows and expose them to the additional stresses of cold weather. Water level manipulation is expensive to implement and has not yet been proven to be effective. Nevertheless, this method should be considered when a comprehensive nutria control program is being developed.

Other Cultural Methods. Alternate field and garden sites should be considered in areas where nutria damage has occurred on a regular basis. New fields, gardens, and slab-on-grade buildings should be located as far as possible from drainages, waterways, and other water bodies where nutria live.

Late-planted baldcypress seedlings are less susceptible to damage by nutria than those planted in the spring. For this reason, plant unprotected seedlings in the early fall when alternative natural foods are readily available.

Frightening

Nutria are wary creatures and will try to escape when threatened. Loud noises, high pressure water sprays, and other types of harassment have been used to scare nutria from lawns and golf courses. The success of this type of control is usually short-lived and problem animals soon return. Consequently, frightening as a control technique is neither practical nor effective.

Repellents

No chemical repellents for nutria are currently registered. Other rodent repellents (such as Thiram) may repel nutria, but their effectiveness has not been determined. Use of these without the proper state and federal pesticide registrations is illegal.

Toxicants

Zinc Phosphide. Zinc phospide is the only toxicant that is registered for controlling nutria. Zinc phosphide is a Restricted Use Pesticide that can only be purchased and applied by certified pesticide applicators or individuals under their direct supervision. It is a grayish-black powder with a heavy garlic-like smell and is widely used for controlling a variety of rodents. When used properly, zinc phosphide poses little hazard to nontarget species, humans, pets, or livestock.

Zinc phosphide is highly toxic to wildlife and humans, so all precautions and instructions on the product label

should be carefully reviewed, understood, and followed precisely. Use an approved respirator and wear elbow-length rubber gloves when handling this chemical to prevent accidental poisoning. Mix and store baits treated with zinc phosphide only in well-ventilated areas to reduce exposing humans to chemical fumes and dust. When possible, mix zinc phosphide at the baiting site to avoid having to store and transport treated baits. Never transport mixed bait or open zinc phosphide containers in the cab of any vehicle. Store unused zinc phosphide in a dry place in its original watertight container because moisture causes it to deteriorate. Immediately wash off any zinc phosphide that gets on the skin.

Past studies have shown that zinc phosphide can kill over 95% of the nutria present along waterways when applied to fresh baits at a 0.75% (7,500 ppm) rate. Today, the use of zinc phosphide at this concentration is illegal. Federal and state registrations, however, allow lower rates to be used. For example, the label held by USDA-APHIS-ADC (EPA Reg. No. 56228-9) allows for a maximum 0.67% (6,700 ppm) treatment rate. At this rate, approximately 94 pounds (42.7 kg) of bait can be treated with 1 pound (0.4 kg) of 63.2% zinc phosphide concentrate.

Where to Bait. The best places to bait nutria are in waterways, ponds, and ditches where permanent standing water and recent nutria sign are found. Baiting in these areas increases efficiency and reduces the likelihood that nontarget animals will be affected. Small chunks of unpeeled carrots, sweet potatoes, watermelon rind, and apples can be used as bait.

The best baiting stations for large waterways are floating rafts spaced 1/4 to 1/2 mile (0.4 to 0.8 km) apart throughout the damaged area. In ponds, use one raft per 3 acres (1.2 ha). Rafts measuring 4 feet (1.2 m) square or 4 x 8 feet (1.2 x 2.4 m) are easily made from sheets of 3/8- to 3/4-inch (1.0- to 1.9- cm) exterior plywood and 3-inch (7.6-cm) styrofoam flotation. Install a thin wooden strip around the perimeter of the raft's surface to keep bait from rolling into the water. The raft should float 1 to 4 inches (2.5 to 10.2 cm) above the surface and should be anchored to the bottom with a heavy weight or tied to the shore (Fig. 5).

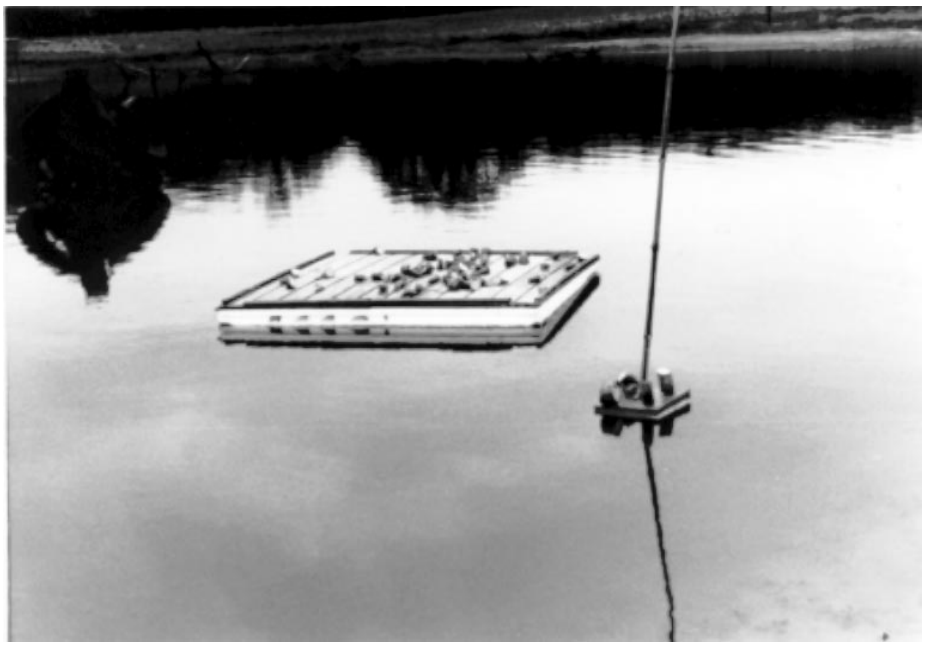


Fig. 5. Examples of a 4-foot (1.2-m) square raft (left) and a 6-inch (15.2-cm) square baiting board, which are used to concentrate nutria for shooting, trapping, or poisoning. These baiting platforms are constructed of plywood and styrofoam and baited with sweet potatoes.

In small ditches or areas where nutria densities are low, use 6-inch (15.2-cm) square floating bait boards made of wood and styrofoam, in lieu of rafts (Fig. 5). These can be maintained in place with a long slender anchoring pole made of bamboo, reed, or other suitable material that is placed through a hole in the center of the platform. This allows the board to move up and down as water levels change. Attach baits to small nails driven into the surface of the platform. Bait boards should be spaced 50 to 100 feet (15.2 to 30.5 m) apart in areas where nutria are active.

Other natural sites surrounded by water can also be baited for nutria. Small islands, exposed tree stumps, floating logs, and feeding platforms are excellent baiting sites. Avoid placing baits on muskrat houses and beaver lodges. Baits can be attached to trees, stumps, or other structures with small nails and should be kept out of the water.

Baiting on the ground should only be used when water sites are unsuitable or lacking. Ground baiting is justified and effective when eliminating the last few nutria in a local population. Use care when ground baiting because baits may be accessible to nontarget animals and humans. Place ground baits near sites of nutria activity, such as trails and entrances to burrows.

Prebaiting. Prebaiting is a crucial step when using zinc phosphide because it leads to nutria feeding at specific sites on specific types of food (such as the baits; carrots or sweet potatoes are preferred). Nutria tend to be communal feeders, and if one nutria finds a new feeding spot, other nutria in the area will also begin feeding there.

To prebait, lightly coat small (approximately 2-inch [5.1-cm] long) chunks of untreated bait with corn oil. Place the bait at each baiting station in late afternoon, and leave it overnight. Use no more than 10 pounds (4.5 kg) of bait per raft, 4 pieces of bait per baiting board, or 2 to 5 pieces at other sites at one time. Prebaiting should continue at least 2 successive nights after nutria begin feeding at a baiting site. Large

(more than 1 week) gaps in the prebaiting sequence necessitate that the process be started over.

Observations of prebaited sites will help you decide how the control program should proceed. If nontarget animals are feeding at these sites (as determined by sign or actual observations of animals), then prebaiting should start over at another location. Prepare and apply zinc phosphide-treated baits when nutria become regular users of prebaited baiting stations and nontarget animals are not a problem.

Applying Zinc Phosphide. Prepare zinc phosphide baits as needed to prevent deterioration. Treated baits are prepared in 10-pound (4.5-kg) batches (enough to treat one raft) by using the following ingredients: 10 pounds (4.5 kg) of bait (carrots or sweet potatoes are preferred), prepared as for prebaiting; 1 fluid ounce or 2 tablespoons (30 ml) of corn oil; and 1.7 ounces or 7.5 tablespoons (48.2 g) of 63.2% zinc phosphide concentrate.

To prepare treated baits, add corn oil to the bait in a 5 gallon (18.9 l) plastic or metal container. Stir the mixture until the bait is lightly coated with corn oil. Sprinkle zinc phosphide over the mixture and stir until the bait is uniformly coated. Treated baits have a shiny black appearance and should be dried for about 1 hour in a well-ventilated area until the color changes to a dull gray. Properly dried baits are weather-resistant and remain toxic until they deteriorate. Although treated baits can survive light rain, they should not be used when heavy rains are expected or on open water that is subject to heavy wave action.

The amount of untreated bait eaten the last night of prebaiting determines how much treated bait should be used on the first night. When all or most of the untreated prebait is gone from baiting stations by morning, the same amount of treated bait is used on the stations the following night (e.g., up to 10 pounds [4.5 kg] per raft, 4 pieces per baiting board, and 2 to 5 pieces at other sites). When smaller quantities are eaten, reduce the amount of treated bait that is used per station proportionately. When only a few pieces of prebait on a raft are eaten, the raft should be removed and replaced with several scattered baiting boards.

The quantity of treated bait eaten each treatment night is the quantity that should be put out the following afternoon. Continue baiting until no more bait is being taken. Most nutria can be controlled after 4 nights of baiting. When densities are high, control may require more time.

Post-Control Procedures. Usually only 25% of the poisoned nutria die where they can be found. Many nutria die in dens, dense vegetation, and other inaccessible areas. Carcasses of nutria killed with zinc phosphide should be collected as soon as possible and disposed of by deep burial or burning to prevent exposure of domestic and wild scavengers to undigested stomach material containing zinc phosphide. Dispose of any leftover treated bait in accordance with label directions.

Cessation of damage is the best indicator that zinc phosphide is controlling problem animals. You can quantify the reduction in nutria activity by putting out untreated bait at baiting stations after the last application of zinc phosphide. The amount eaten at this time is compared to the amount of bait eaten on the last night of prebaiting.

Fumigants

Several fumigants are registered for controlling burrowing rodents but none are registered for use against nutria. Some, such as aluminum phosphide, may have potential as nutria control agents, but their efficacy has not been scientifically demonstrated. Carbon monoxide gas pumped into dens has reportedly been used to kill nutria, but this method is neither practical nor legal because it is not registered for this purpose.

Trapping

Commercial Harvest. Damage to crops, levees, wetlands, and other resources is minimal in areas where nutria are harvested by commercial trappers. The commercial harvest of nutria on private and public lands should be encouraged as part of an overall program to manage nutria-caused damage. Landowners may be able to obtain additional information on nutria management, trapping, and a list of licensed trappers in their area from their state wildlife agency.

Leghold traps. Leghold traps are the most commonly used traps for catching nutria. Double longspring traps, No. 11 or 2, are preferred by most trappers; however, the No. 1 1/2 coilspring, No. 3 double longspring, or the soft-catch fox trap can also be used effectively. Legholds are more efficient and versatile than body-grip traps and are highly recommended for nutria control work. Leghold traps should be used with care to prevent injury to children and pets.

Several ways of setting leghold traps are effective. Set traps just under the water where a trail enters a ditch, canal, or other body of water. Make trail sets by placing a trap offset from the trail's center line so that nutria are caught by the foot. Traps can be lightly covered with leaves or other debris to hide them, but nutria are easily captured in unconcealed traps.

Bait can be used to lure nutria to leghold sets. Nutria use their teeth to pick up large pieces of food; therefore, bait should be placed beside, rather than inside, the trap jaws. Leghold traps are also effective when set on floating rafts that have been prebaited for a short period of time.

Use drowning sets when deep water is available. Otherwise, stake leghold traps to the ground, or anchor them to solid objects in the water or on land (such as floating logs, stumps, or trees and shrubs). Nutria caught in non-drowning leghold sets should be humanely dispatched with a shot or hard blow to the head. Nontarget animals should be released.

Live Traps. Nutria are easily captured in single- or double-door live traps that measure 9 x 9 x 32 inches (22.8 x 22.8 x 81.3 cm) or larger. Use

Fig. 6. Hand-caught nutria must be handled carefully to avoid being bitten or clawed.

these when leghold and body-grip traps cannot be set or when animals are to be translocated. Bait live traps with sweet potatoes and carrots and place them along active trails or wherever nutria or their sign are seen. A short line of baits leading to the entrance of a live trap will increase capture success. Live traps placed on floating rafts will effectively catch nutria but prebaiting is necessary. A large raft can hold up to 8 traps. Unwanted nutria should be destroyed with a shot or blow to the head. Nontarget animals should be released.

Floating, drop-door live traps catch nutria but are bulky and cumbersome to use. The same is true for expensive suitcase-type beaver traps. Unwary nutria can be captured using a long-handled dip net. This method should only be used by trained damage control professionals who should take special precautions to prevent being bitten or clawed (Fig. 6). Live nutria can be immobilized with an injection of ketamine hydrochloride. Funnel traps are not effective for controlling nutria.

Body-gripping Traps. The Conibear® trap, No. 220-2, is the most commonly used body-gripping trap for controlling nutria. Nos. 160-2 and 330-2 Conibear® traps can also be used. Place sets in trails, at den entrances, in culverts, and in narrow waterways. Large body-grip traps can be dangerous and should be handled with extreme caution. These traps should not be set in areas frequented by children, pets, or desirable wildlife species.

Other Traps. Use locking snares to catch nutria when other traps cannot be set. Snares are relatively easy to set, safer than leghold and body-grip traps, and almost invisible to the casual observer. Snares constructed with 3/32-inch (0.2-cm) diameter, flexible (7 x 7-winding) stainless steel or galvanized aircraft cable are suitable for catching nutria. Ready-made snares and components (for example, cable, one-way cable locks, swivels, and cable stops) for making homemade snares can be purchased from trapping suppliers.

Place set snares in trails and other travel routes, feeding lanes, trails, and bank slides. Snares do not kill the animals they catch, so anchor the snare securely. Check snares frequently because they are often knocked down by nutria and other animals. Snared nutria should be dispatched with a shot or blow to the head. Release any nontarget animals that are captured.

Shooting

Shooting can be used as the primary method of nutria control or to supplement other control techniques. Shooting is most effective when done at night with a spotlight, however, night shooting is illegal in many states and should not be done until proper permits have been obtained. Once shooting has been approved by the proper authorities, nutria can be shot from the banks of waterways and other bodies of water or from boats. In some cases, 80% of the nutria in an area can be removed by shooting with a shotgun or small caliber rifle, such as the .22 rimfire. Care should be taken when shooting over open water to prevent bullets from ricocheting.

Shooting at Bait Stations. Baits can attract large numbers of nutria to floating rafts, baiting boards, and other areas where they can be shot. Shooting from dusk to about 10:00 p.m. for 3 consecutive nights is effective once a regular feeding pattern has been established. Feeding sites should be lit continuously by a spotlight and easily visible to the shooter from a vehicle or other stationary blind. At night, nutria can be located by their red-shining eyes and the V-shaped wake left by swimming animals. As many as 4 to 5 nutria per hour may be taken by this method. Shooters should wait 2 to 3 weeks before shooting nutria at the same site again.

Boat Shooting. Shooting can also be done in the late afternoon or early evening from a small boat paddled slowly along waterways and large ditches or along the shores of small lakes and ponds. Nutria are especially vulnerable to this method when water levels are extremely high or vegetative

cover is scarce. At times, animals can be stimulated to vocalize or decoyed to a boat or blind by making a "maw" call, which imitates the nutria's nocturnal feeding and assembly call. This call can be learned from someone who knows it or by listening to nutria vocalizations at night. Nutria become wary quickly, so limit shooting to no more than 3 nights, followed by 2 to 3 weeks of no activity.

Bank Shooting. Nutria can be shot by slowly stalking along the banks of ditches and levees; this can be an effective control method where nutria have not been previously harassed. Unlike night shooting from a boat or blind, bank shooting is most effective at twilight, both in the evening and morning. Several nutria can usually be shot the first night, however, success decreases with each successive night of shooting. Daytime shooting from the bank of a waterway is effective in some situations.

Economics of Damage and Control

Nutria can have either positive or negative values. They are economically important furbearers when their pelts provide income to commercial trappers. Conversely, they are considered pests when they damage property.

From 1977 to 1984, an average of 1.3 million nutria pelts were harvested annually in the United States. Based on prices paid to Louisiana trappers during this period, these pelts were worth about $7.3 million.

The estimated value of sugarcane and rice damaged by nutria each year has ranged from several thousand dollars to over a million dollars. If losses of other resources are added to this amount, the estimated average loss would probably exceed $1 million annually.

Management plans developed for nutria should be comprehensive and should consider the needs of all stakeholders. Regulated commercial trapping should be an integral part of any management scheme because it can provide continuous, long-term income to trappers; maintain acceptable nutria densities; and reduce damage to tolerable levels.

The value of the protected resource must be compared with the cost of control when determining whether nutria control is economically feasible. Most people will not control nutria if costs exceed the value of the resource being protected or if control will adversely impact income derived from trapping. Of course, there are exceptions, especially when the resource has a high sentimental or aesthetic value to the owner or user.

Acknowledgments

This chapter is a revision of an earlier chapter written by Evans (1983). Kinler et al. (1987) and Willner (1982) were the primary sources consulted for biological information on nutria.

Figures 1 and 3 by Peggy A. Duhon of Lafayette, Louisiana.

Figure 2 from Willner (1982) and reprinted with permission of The Johns Hopkins University Press, Baltimore, Maryland.

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Sanford D. Schemnitz
Professor of Wildlife Science
New Mexico State University
Las Cruces, New Mexico 88003

PORCUPINES

Fig. 1. Porcupine, *Erethizon dorsatum*

Damage Prevention and Control Methods

Exclusion

Fences (small areas).

Tree trunk guards.

Cultural Methods

Encourage closed-canopy forest stands.

Repellents

None are registered.

Some wood preservatives may incidentally repel porcupines.

Toxicants

None are registered.

Fumigants

None are registered.

Trapping

Steel leghold trap (No. 2 or 3).

Body-gripping (Conibear®) trap (No. 220 or 330).

Box trap.

Shooting

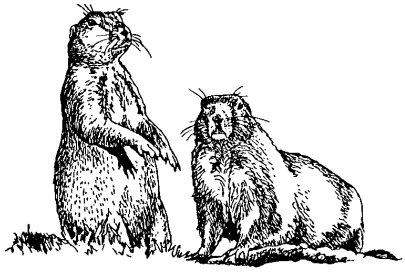
Day shooting and spotlighting are effective where legal.

Other Methods

Encourage natural predators.

Identification

Porcupines (*Erethizon dorsatum*), sometimes called "porkies" or "quill pigs," (Fig. 1) are heavy-bodied, short-legged, slow, and awkward rodents, with a waddling gait. Adults are typically 25 to 30 inches (64 to 76 cm) long and weigh 10 to 30 pounds (4.5 to 13.5 kg). They rely on their sharp, barbed quills (up to 30,000 per individual) for defense.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

B-81

Range and Habitat

The porcupine is a common resident of the coniferous forests of western and northern North America (Fig. 2). It wanders widely and is found from cottonwood stands along prairie river bottoms and deserts to alpine tundra.

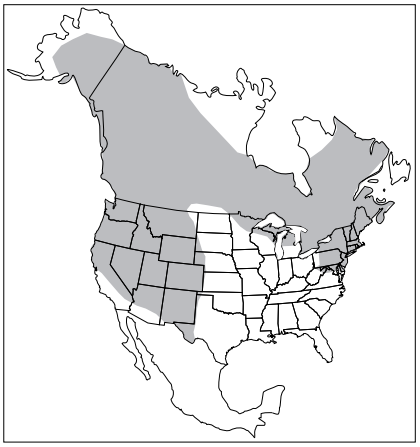


Fig. 2. Range of the porcupine in North America.

Food Habits

Porcupines eat herbaceous plants, inner tree bark, twigs, and leaves, with an apparent preference for ponderosa pine, aspen, willow, and cottonwood. Trees with thin, smooth bark are preferred over those with thick, rough bark. Porcupine feeding is frequently evident and has considerable impact on the cottonwood stands of western river bottoms.

General Biology, Reproduction, and Behavior

Porcupines breed in autumn, and after a 7-month gestation period usually produce 1 offspring in spring. Although the young are capable of eating vegetation within a week after birth, they generally stay with the female through the summer. Juvenile survival rates are high.

Predators of porcupines include coyotes, bobcats, mountain lions, black bears, fishers, martens, great horned owls, and others. Coyote scats (feces) containing large numbers of quills are not unusual. How the quills are maneuvered through the coyote's gastrointestinal tract is a mystery.

Porcupines are active year-round and are primarily nocturnal, often resting in trees during the day. They favor caves, rock slides, and thick timber downfalls for shelter.

Damage and Damage Identification

Clipped twigs on fresh snow, tracks, and gnawings on trees are useful means of damage identification (Fig. 3). Trees are often deformed from partial girdling. Porcupines clip twigs and branches that fall to the ground or onto snow and often provide food for deer and other mammals. The considerable secondary effects of their feeding come from exposing the tree sapwood to attack by disease, insects, and birds. This exposure is important to many species of wildlife because diseased or hollow trees provide shelter and nest sites.

Porcupines occasionally will cause considerable losses by damaging fruits, sweet corn, alfalfa, and small grains. They chew on hand tools and other wood objects while seeking salt. They destroy siding on cabins when seeking plywood resins.

Porcupines offer a considerable threat to dogs, which never seem to learn to avoid them. Domestic stock occasionally will nuzzle a porcupine and may be fatally injured if quills are not removed promptly.

Legal Status

Porcupines are considered nongame animals and are not protected.

Damage Prevention and Control Methods

Exclusion

Fencing small tree plantings, orchards, and gardens is effective in reducing porcupine damage. Electric fences are effective when the smooth electric wire is placed 1 1/2 inches (3.8 cm) above

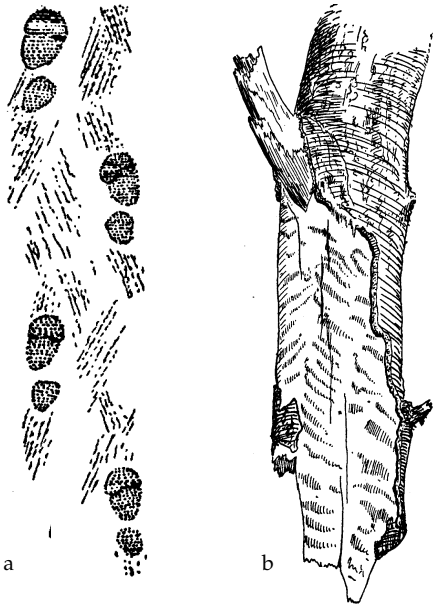


Fig. 3. Porcupine sign: a) tracks showing drag marks of tail; b) toothmarks on tree limbs.

18-inch-high (46-cm) poultry wire. A 4- to 6-inch (10- to 15-cm) electric fence can be enhanced by painting molasses on the wire. Porcupines will climb fences, but an overhanging wire strip around the top of the fence at a 65° angle to the upright wire will discourage them.

Completely enclose small trees with wire baskets or encircle the trunks of fruit and ornamental trees with 30-inch (70-cm) bands of aluminum flashing to reduce damage.

Cultural Methods

Thinned forest stands are vulnerable to porcupine damage because lower vegetation can thrive. Porcupine populations are usually lower in closed canopy stands where understory vegetation is scant.

Repellents

Thiram is registered as a squirrel and rabbit repellent and may incidentally repel porcupines. This material is sprayed or painted on the plants subject to damage. It must be renewed occasionally to remain effective. Common wood preservatives may repel porcupines when applied to exterior plywoods. Avoid using wood preservatives that are metal-salt solutions. These will attract porcupines.

Toxicants

No toxicants can be legally used to control porcupines.

Trapping

Steel leghold traps of size No. 2 or 3 can be used to catch porcupines where legal. Cubby sets with salt baits, trail sets in front of dens, and coyote urine scent post sets near dens and damage activity are effective. Scent post and trail sets must be checked daily to release nontarget animals that might be caught. Leghold traps should be bedded, firmly placed and leveled, and offset slightly to the side of the trail. The trapped porcupine can be shot or killed by a sharp blow to the head.

The No. 220 or 330 Conibear® body-gripping trap can be baited with a salt-soaked material or placed in den entrances to catch and kill porcupines. Care must be taken to avoid taking nontarget animals, since salt attracts many animals. The Conibear® trap does not allow the release of accidental catches. Some states do not allow the use of No. 330 Conibear® traps for ground sets.

Porcupines are rather easy to livetrap with large commercial cage traps (32 x 10 x 12 inches [81 x 25 x 30.5 cm]) or homemade box traps. Place the live trap in the vicinity of damage and bait with a salt-soaked cloth, sponge, or piece of wood. Live traps also can be set at den entrances. Move the porcupine 25 miles (40 km) or more to ensure that it does not return. Since most areas of suitable habitat carry large porcupine populations, relocation of the porcupine often is neither helpful nor humane since the introduced animal may have a poor chance of survival.

Shooting

Persistent hunting and shooting of porcupines can be effective in reducing the population in areas that require protection. Night hunting, where legal, is effective. During winter months, porcupines are active and can be tracked in the snow and shot with a .22-caliber rifle or pistol. Porcupines often congregate around good denning sites and extensively girdle trees in the area. In such places large numbers may be taken by shooting.

Other Considerations

Porcupines are mobile and continually reinvade control areas. Complete control is not desirable since it would require complete removal of porcupines. Try to limit lethal porcupine control to individual animals causing damage by fencing and management of the plant species. In areas of high porcupine populations, plant ornamentals that are not preferred foods. Intensive predator control may encourage porcupine population increases.

Economics of Damage and Control

Economic losses can be considerable from porcupines feeding on forest plantings, ornamentals, and orchards as well as on leather and other human implements. Porcupines generally are tolerated except when commercial timber, high-value ornamental plantings, orchards, or nursery plants are damaged by girdling, basal gnawing, or branch clipping. On occasion, porcupines thin dense, crowded forest stands. Often tree diameter growth is reduced. Their preference for mistletoe as a food is an asset.

The porcupine is acclaimed as a beautiful creature of nature. It is an interesting animal that has an important place in the environment. It is edible and has been used by humans as an emergency food. The quills are used for decorations, especially by Native Americans. The hair, currently used for fly-fishing lures, commands many dollars per ounce. Porcupines are not wary and can be readily observed and photographed by nature lovers. Porcupines may need to be controlled but should not be totally eradicated.

Acknowledgments

Some of the information for this chapter was taken from a chapter by Major L. Boddicker in the 1980 edition of *Prevention and Control of Wildlife Damage.*

Figure 1 by Emily Oseas Routman.

Figure 2 adapted from Burt and Grossenheider (1976) by Jill Sack Johnson.

Figure 3 adapted from Murie (1954) by Renee Lanik, University of Nebraska-Lincoln.

For Additional Information

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Scott E. Hygnstrom
Extension Wildlife Damage Specialist
Department of Forestry, Fisheries and Wildlife
University of Nebraska
Lincoln, NE 68583-0819

Dallas R. Virchow
Extension Assistant-Wildlife Damage
Panhandle Research and Extension Center
University of Nebraska
Scottsbluff, NE 69361

PRAIRIE DOGS

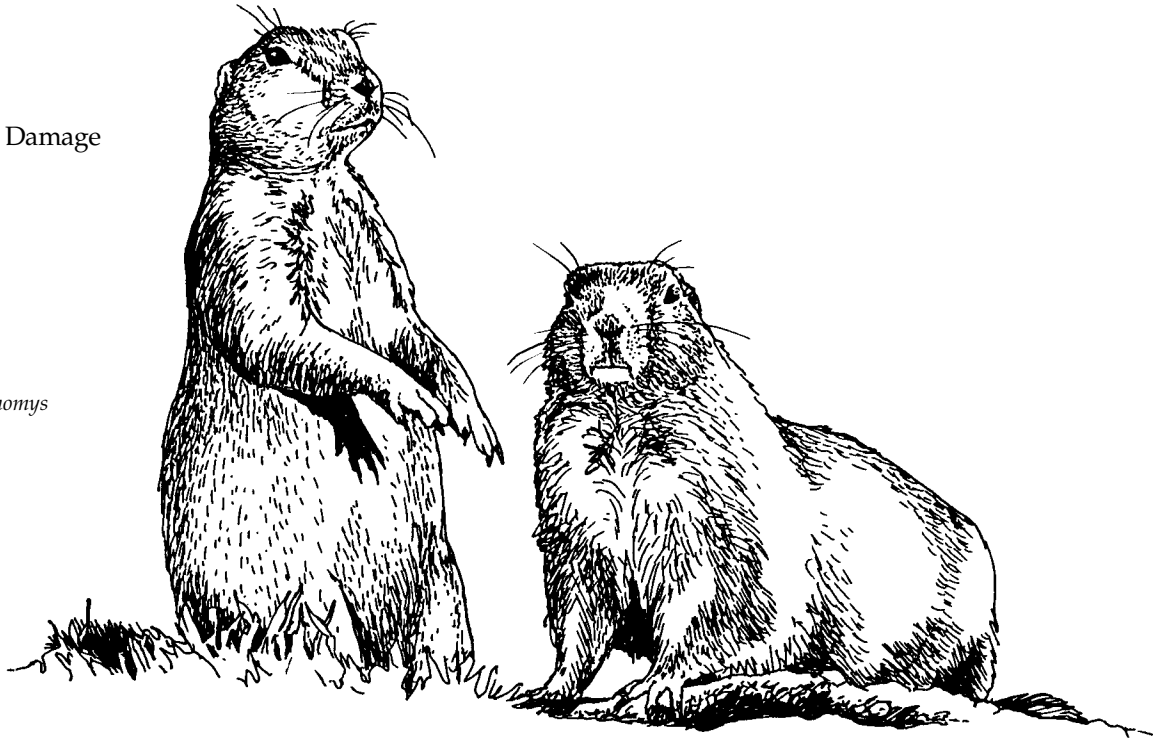


Fig. 1. Black-tailed prairie dogs, *Cynomys ludovicianus*

Damage Prevention and Control Methods

Exclusion

Wire mesh fences can be installed but they are usually not practical or cost-effective.

Visual barriers of suspended burlap, windrowed pine trees, or snow fence may be effective.

Cultural Methods

Modify grazing practices on mixed and mid-grass rangelands to exclude or inhibit prairie dogs.

Cultivate, irrigate, and establish tall crops to discourage prairie dog use.

Frightening

No methods are effective.

Repellents

None are registered.

Toxicants

Zinc phosphide.

Fumigants

Aluminum phosphide.

Gas cartridges.

Trapping

Box traps.

Snares.

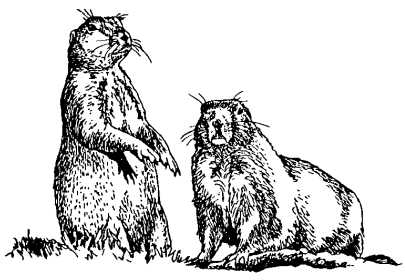
Conibear® No. 110 (body-gripping) traps or equivalent.

Shooting

Shooting with .22 rimfire or larger rifles.

Other Methods

Several home remedies have been used but most are unsafe and are not cost-effective.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

B-85

Identification

Prairie dogs (Fig. 1) are stocky burrowing rodents that live in colonies called "towns." French explorers called them "little dogs" because of the barking noise they make. Their legs are short and muscular, adapted for digging. The tail and other extremities are short. Their hair is rather coarse with little underfur, and is sandy brown to cinnamon in color with grizzled black and buff-colored tips. The belly is light cream to white.

Five species of prairie dogs are found in North America: the black-tailed (*Cynomys ludovicianus*), Mexican (*C. mexicanus*), white-tailed (*C. leucurus*), Gunnison's (*C. gunnisoni*), and Utah prairie dog (*C. parvidens*). The most abundant and widely distributed of these is the black-tailed prairie dog, which is named for its black-tipped tail. Adult black-tailed prairie dogs weigh 2 to 3 pounds (0.9 to 1.4 kg) and are 14 to 17 inches (36 to 43 cm) long. The Mexican prairie dog also has a black-tipped tail, but is smaller than its northern relative. White-tailed, Gunnison's, and Utah prairie dogs all have white-tipped tails. White-tailed prairie dogs are usually smaller than black-tailed prairie dogs, weighing between 1 1/2 and 2 1/2 pounds (0.7 to 1.1 kg). The Gunnison's prairie dog is the smallest of the five species.

Range

Prairie dogs occupied up to 700 million acres of western grasslands in the early 1900s. The largest prairie dog colony on record, in Texas, measured nearly 25,000 square miles (65,000 km^2) and contained an estimated 400 million prairie dogs. Since 1900, prairie dog populations have been reduced by as much as 98% in some areas and eliminated in others. This reduction is largely the result of cultivation of prairie soils and prairie dog control programs implemented in the early and mid-1900s. Population increases have been observed in the 1970s and 1980s, possibly due to the increased restrictions on and reduced use of toxicants.

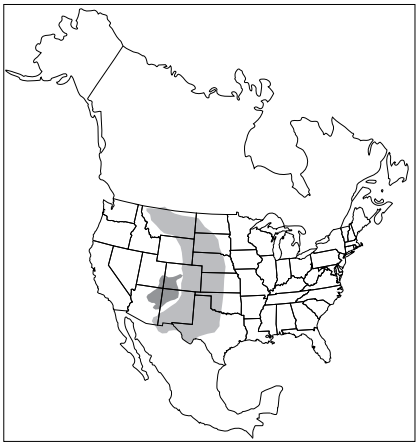


Fig. 2a. Distribution of the black-tailed (light), and Gunnison's prairie dogs (dark) in North America.

Fig. 2b. Distribution of the white-tailed (light), Utah (medium), and Mexican prairie dogs (dark) in North America.

Today, about 2 million acres of prairie dog colonies remain in North America.

The black-tailed prairie dog lives in densely populated colonies (20 to 35 per acre [48 to 84/ha]) scattered across the Great Plains from northern Mexico to southern Canada (Fig 2). Occasionally they are found in the Rocky Mountain foothills, but rarely at elevations over 8,000 feet (2,438 m). The Mexican prairie dog occurs only in Mexico and is an endangered species. White-tailed prairie dogs live in sparsely populated colonies in arid regions up to 10,000 feet (3,048 m). The Gunnison's prairie dog inhabits open grassy and brushy areas up to 12,000 feet (3,658 m). Utah prairie dogs are a threatened species, limited to central Utah.

Habitat

All species of prairie dogs are found in grassland or short shrubland habitats. They prefer open areas of low vegetation. They often establish colonies near intermittent streams, water impoundments, homestead sites, and windmills. They do not tolerate tall vegetation well and avoid brush and timbered areas. In tall, mid- and mixed-grass rangelands, prairie dogs have a difficult time establishing a colony unless large grazing animals (bison or livestock) have closely grazed vegetation. Once established, prairie dogs can maintain their habitat on mid- and mixed-grass rangelands. In shortgrass prairies, where moisture is limited, prairie dogs can invade and maintain acceptable habitat without assistance.

Food Habits

Prairie dogs are active above ground only during the day and spend most of their time foraging. In the spring and summer, individuals consume up to 2 pounds (0.9 kg) of green grasses and forbs (broad-leafed, nonwoody plants) per week. Grasses are the preferred food, making up 62% to 95% of their diet. Common foods include western wheatgrass, blue grama, buffalo grass, sand dropseed, and sedges. Forbs such as scarlet globe mallow, prickly pear, kochia, peppergrass, and wooly plantain are common in prairie dog diets and become more important in the fall, as green grass becomes scarce. Prairie dogs also eat flowers, seeds, shoots, roots, and insects when available.

General Biology, Reproduction, and Behavior

Prairie dogs are social animals that live in towns of up to 1,000 acres (400 ha) or more. Larger towns are often divided into wards by barriers such as ridges, lines of trees, and roads. Within a ward, each family or "coterie" of prairie dogs occupies a territory of about 1 acre (0.4 ha). A coterie usually consists of an adult male, one to four

adult females, and any of their offspring less than 2 years old. Members of a coterie maintain unity through a variety of calls, postures, displays, grooming, and other forms of physical contact.

Black-tailed prairie dog towns typically have 30 to 50 burrow entrances per acre, while Gunnison's and white-tailed prairie dog towns contain less than 20 per acre. Most burrow entrances lead to a tunnel that is 3 to 6 feet (1 to 2 m) deep and about 15 feet (5 m) long. Prairie dogs construct crater- and dome-shaped mounds up to 2 feet (0.6 m) high and 10 feet (3 m) in diameter. The mounds serve as lookout stations. They also prevent water from entering the tunnels and may enhance ventilation of the tunnels.

Prairie dogs are most active during the day. In the summer, during the hottest part of the day, they go below ground where it is much cooler. Black-tailed prairie dogs are active all year, but may stay underground for several days during severe winter weather. The white-tailed, Gunnison's, and Utah prairie dogs hibernate from October through February.

Black-tailed prairie dogs reach sexual maturity after their second winter and breed only once per year. They can breed as early as January and as late as March, depending on latitude. The other four species of prairie dogs reach sexual maturity after their first winter and breed in March. The gestation period is about 34 days and litter sizes range from 1 to 6 pups. The young are born hairless, blind, and helpless. They remain underground for the first 6 weeks of their lives. The pups emerge from their dens during May or June and are weaned shortly thereafter. By the end of fall, they are nearly full grown. Survival of prairie dog pups is high and adults may live from 5 to 8 years.

Even with their sentries and underground lifestyle, predation is still a major cause of mortality for prairie dogs. Badgers, weasels, and black-footed ferrets are efficient predators. Coyotes, bobcats, foxes, hawks, and eagles also kill prairie dogs. Prairie rattlesnakes and bull snakes may take young, but rarely take adult prairie dogs. Accidents, starvation, weather, parasites, and diseases also reduce prairie dog populations, but human activities have had the greatest impact.

Prairie dog colonies attract a wide variety of wildlife. One study identified more than 140 species of wildlife associated with prairie dog towns. Vacant prairie dog burrows serve as homes for cottontail rabbits, small rodents, reptiles, insects, and other arthropods. Many birds, such as meadowlarks and grasshopper sparrows, appear in greater numbers on prairie dog towns than in surrounding prairie. The burrowing owl is one of several uncommon or rare species that frequent prairie dog towns. Others include the golden eagle, prairie falcon, ferruginous hawk, mountain plover, swift fox, and endangered black-footed ferret (see Appendix A of this chapter).

Damage and Damage Identification

Several independent studies have produced inconsistent results regarding the impacts of prairie dogs on livestock production. The impacts are difficult to determine and depend on several factors, such as the site conditions, weather, current and historic plant communities, number of prairie dogs, size and age of prairie dog towns, and the intensity of site use by livestock and other grazers. Prairie dogs feed on many of the same grasses and forbs that livestock feed on. Annual dietary overlap ranges from 64% to 90%. Prairie dogs often begin feeding on pastures and rangeland earlier in spring than cattle do and clip plants closer to the ground. Up to 10% of the aboveground vegetation may be destroyed due to their burrowing and mound-building activities. Overall, prairie dogs may remove 18% to 90% of the available forage through their activities.

The species composition of pastures occupied by prairie dogs may change dramatically. Prairie dog activities encourage shortgrass species, perennials, forbs, and species that are resistant to grazing. Annual plants are selected against because they are usually clipped before they can produce seed. Several of the succeeding plant species are less palatable to livestock than the grasses they replace.

Other studies, however, indicate that prairie dogs may have little or no significant effect on livestock production. One research project in Oklahoma revealed that there were no differences in annual weight gains between steers using pastures inhabited by prairie dogs and steers in pastures without prairie dogs. Reduced forage availability in prairie dog towns may be partially compensated for by the increased palatability and crude protein of plants that are stimulated by grazing. In addition, prairie dogs sometimes clip and/or eat plants that are toxic to livestock. Bison, elk, and pronghorns appear to prefer feeding in prairie dog colonies over uncolonized grassland.

Prairie dog burrows increase soil erosion and are a potential threat to livestock, machinery, and horses with riders. Damage may also occur to ditch banks, impoundments, field trails, and roads.

Prairie dogs are susceptible to several diseases, including plague, a severe infectious disease caused by the bacterium *Yersinia pestis*. Plague, which is often fatal to humans and prairie dogs, is most often transmitted by the bite of an infected flea. Although plague has been reported throughout the western United States, it is uncommon. Symptoms in humans include swollen and tender lymph nodes, chills, and fever. The disease is curable if diagnosed and treated in its early stages. It is important that the public be aware of the disease and avoid close contact with prairie dogs and other rodents. Public health is a primary concern regarding prairie dog colonies that are in close proximity to residential areas and school yards.

Rattlesnakes and black widow spiders also occur in prairie dog towns, but can be avoided. Rattlesnakes often rest in prairie dog burrows during the day and move through towns at night in search of food. Black widow spiders are most often found in abandoned prairie dog holes where they form

webs and raise their young. Bites from these animals are rare, but are a threat to human health.

Legal Status

Black-tailed, white-tailed, and Gunnison's prairie dogs are typically classified as unprotected or nuisance animals, allowing for their control without license or permit. Most states require purchase of a small game license to shoot prairie dogs. If the shooter is acting as an agent for the landowner to reduce prairie dog numbers, a license may not be required. The Utah and Mexican prairie dogs are classified as threatened and endangered species, respectively. Contact your local wildlife agency for more information.

The black-footed ferret is an endangered species that lives almost exclusively in prairie dog towns, and all active prairie dog colonies are potential black-footed ferret habitat. It is a violation of federal law to willfully kill a black-footed ferret or poison prairie dog towns where ferrets are present. Federal agencies must assess their own activities to determine if they "may affect" endangered species. Some pesticides registered for prairie dog control require private applicators to conduct ferret surveys before toxicants can be applied. Detailed information on identifying black-footed ferrets and their sign is included in Appendix A of this chapter. To learn more about federal and state guidelines regarding prairie dog control, black-footed ferret surveys, and block clearance procedures, contact personnel from your local Cooperative Extension, USDA-APHIS-ADC, US Fish and Wildlife Service, or state wildlife agency office.

Damage Prevention and Control Methods

Exclusion

Fencing. Exclusion of prairie dogs is rarely practical, although they may be discouraged by tight-mesh, heavy-gauge, galvanized wire, 5 feet (1.5 m) wide with 2 feet (60 cm) buried in the ground and 3 feet (90 cm) remaining aboveground. A slanting overhang at the top increases the effectiveness of the fence.

Visual Barriers. Prairie dogs graze and closely clip vegetation to provide a clear view of their surroundings and improve their ability to detect predators. Fences, hay bales, and other objects can be used to block prairie dogs' view and thus reduce suitability of the habitat. Franklin and Garrett (1989) used a burlap fence to reduce prairie dog activity over a two-month period. Windrows of pine trees also reduced prairie dog activity. Unfortunately, the utility of visual barriers is limited because of high construction and maintenance costs. Tensar snow fences (2 feet [60 cm] tall) are less costly, at about $0.60 per foot ($1.97/m) for materials. Unfortunately, they were inconsistent in reducing reinvasion rates of prairie dog towns in Nebraska (Hygnstrom and Virchow, unpub. data).

Cultural Methods

Grazing Management. Proper range management can be used to control prairie dogs. Use stocking rates that maintain sufficient stand density and height to reduce recolonization of previously controlled prairie dog towns or reduce occupation of new areas. The following general recommendations were developed with the assistance of extension range management specialists and research scientists.

Stocking Rate. Overgrazed pastures are favorable for prairie dog town establishment or expansion. If present, prairie dogs should be included in stocking rate calculations. At a conservative population density of 25 prairie dogs per acre (60/ha) and dietary overlap of 75%, it takes 6 acres (2.4 ha) of prairie dogs to equal 1 Animal Unit Month (AUM) (the amount of forage that one cow and calf ingest per month during summer [about 900 pounds; 485 kg]).

Rest/Rotation Grazing. Rest pastures for a period of time during the growing season to increase grass height and maintain desired grass species. Instead of season-long continuous grazing, use short duration or rapid rotation grazing systems, or even total deferment during the growing season. Livestock can be excluded from vacant prairie dog towns with temporary fencing to help vegetation regain vigor and productivity. Mid- to tallgrass species should be encouraged where they are a part of the natural vegetation. In semiarid and shortgrass prairie zones, grazing strategies may have little effect on prairie dog town expansion or establishment.

Grazing Distribution. Prairie dogs often establish towns in areas where livestock congregate, such as at watering sites or old homesteads. Move watering facilities and place salt and minerals on areas that are underutilized by livestock to distribute livestock grazing pressure more evenly. Prescribed burns in spring may enhance regrowth of desirable grass species.

Cultivation. Prairie dog numbers can be reduced by plowing or disking towns and leaving the land fallow for 1 to 2 years, where soil erosion is not a problem. Establish tall grain crops after the second year to further discourage prairie dogs. Burrows can be leveled and filled with a tractor-mounted blade to help slow reinvasion. Flood irrigation may discourage prairie dogs.

Frightening

Frightening is not a practical means of control.

Repellents

None are registered.

Toxicants

Safety Precautions. Use pesticides safely and comply with all label recommendations. Only use products that are registered for prairie dog control by the Environmental Protection Agency. Some pesticides registered for prairie dog control require that private applicators conduct ferret surveys before toxicants can be applied. Detailed information on identifying black-footed ferrets and their sign is included in Appendix A of this

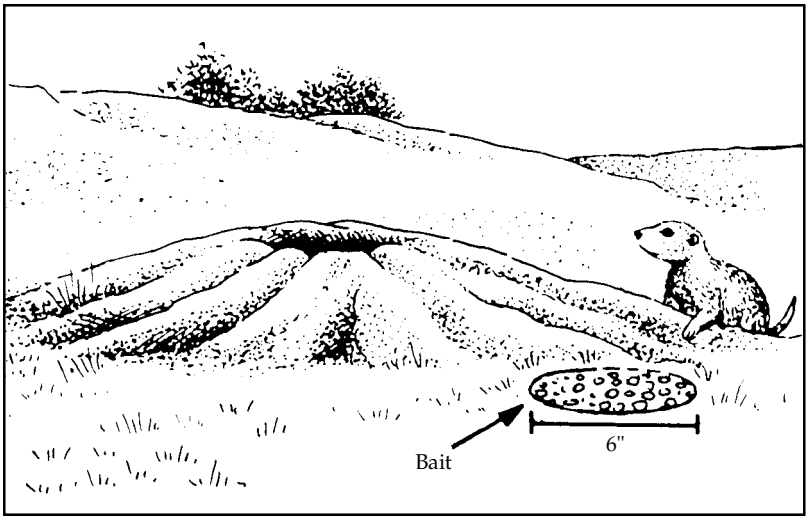


Fig. 3. Prebait and toxic bait should be scattered over a 6-inch (15-cm) circle at each burrow entrance.

chapter. Seek assistance from your local extension agent or from the USDA-APHIS-ADC if needed.

Toxic Bait. The only toxic baits currently registered and legal for use to control prairie dogs are 2% zinc phosphide-treated grain bait and pellet formulations. Zinc phosphide baits are effective and relatively safe regarding livestock and other wildlife in prairie dog towns, if used properly. These baits are available through national suppliers (see **Supplies and Materials**), USDA-APHIS-ADC, and local retail distributors.

Toxic baits are most effective when prairie dogs are active and when there is no green forage available. Therefore, it is best to apply baits in late summer and fall. Zinc phosphide baits can only be applied from July 1 through January 31.

Prebaiting. Prairie dog burrows must be prebaited before applying toxic bait. Prebaiting will accustom prairie dogs to eating grain and will make the toxic bait considerably more effective when it is applied. Use clean rolled oats as a prebait if you are using 2% zinc phosphide-treated rolled oats. Drop a heaping teaspoon (4 g) of untreated rolled oats on the bare soil at the edge of each prairie dog mound or in an adjacent feeding area. The prebait should scatter, forming about a 6-inch (15-cm) circle (Fig. 3). Do not place the prebait in piles or inside burrows, on top of mounds, among prairie dog droppings, or in vegetation far from the mound.

Apply toxic bait only after the prebait has been readily eaten, which usually takes 1 to 2 days. If the prebait is not accepted immediately, wait until it is eaten readily before applying the toxic bait. More than one application of prebait may be necessary if rain or snow falls on the prebait. Prohibit shooting and other disturbance of the colony at least 6 weeks prior to and during treatment.

Prebait and toxic bait can be applied by hand on foot, but mechanical bait dispensers attached to all-terrain vehicles are more convenient and cost-effective for towns greater than 20 acres (8 ha). Motorcycles and horses can also be used to apply prebait and toxic bait. See **Supplies and Materials** for information on bait dispensers.

Bait Application. Apply about 1 heaping teaspoon (4 g) of grain bait per burrow in the same way that the prebait was applied. About 1/3 pound of prebait and 1/3 pound of zinc phosphide bait are needed per acre (0.37 kg/ha). Excess bait that is not eaten by prairie dogs can be a hazard to nontarget wildlife or livestock. It is best to remove livestock, especially horses, sheep, or goats, from the pasture before toxic bait is applied; however, removal is not required. Apply toxic bait early in the day for best results and restrict any human disturbance for 3 days following treatment. Always wear rubber gloves when handling zinc phosphide-treated baits. Follow all label directions and observe warnings regarding bait storage and handling.

Apply prebait and bait during periods of settled weather, when vegetation is dry and dormant. Avoid baiting on wet, cold, or windy days. Bait acceptance is usually best after August 1st or when prairie dogs are observed feeding on native seeds and grains. Do not apply zinc phosphide to a prairie dog town more than once per year. If desired, survivors can be removed by fumigation or shooting. Treatment with toxic baits, followed by a fumigant cleanup, is most cost-effective for areas of more than 5 acres (2 ha).

Inspection and evaluation. Inspect treated prairie dog towns 2 to 3 days after treatment. Remove and burn or bury any dead prairie dogs that are aboveground to protect any other animals from indirect poisoning. Success rates of 75% to 85% can usually be obtained with zinc phosphide if it is applied correctly.

To evaluate the success of a treatment, mark and plug 100 burrows 3 days prior to treatment. Count the reopened burrows 24 hours later. Replug the same 100 burrows 3 days after treatment and again count the reopened burrows 24 hours later. Divide the number of reopened burrows (post-treatment) by the number of reopened burrows (pretreatment) to determine the survival rate. Abandoned burrows are usually filled with spider webs, vegetation, and debris. Active burrows are clean and surrounded by tracks, diggings, and fresh droppings at the entrances.

Zinc phosphide is a Restricted Use Pesticide, available for sale to and use by certified pesticide applicators or their designates. Contact your county extension office for information on acquiring EPA certification. Treatment of a prairie dog town with zinc phosphide-treated baits cost about $10 per acre ($25/ha) (includes materials and labor).

Fumigants

Fumigants, including aluminum phosphide tablets and gas cartridges, can provide satisfactory control of prairie dogs in some situations. We do not

recommend fumigation as the primary means of control for large numbers of prairie dogs because it is costly, time-consuming, and usually more hazardous to desirable wildlife species than toxic baits. Fumigants cost about 5 to 10 times more per acre (ha) to apply than toxic baits. Therefore, fumigation is usually used during spring as a follow-up to toxic bait treatment. Success rates of 85% to 95% can usually be obtained if fumigants are applied correctly.

For best results, apply fumigants in spring when soil moisture is high and soil temperature is greater than 60° F (15° C). Fumigation failures are most frequent in dry, porous soils. Spring applications are better than fall applications because all young prairie dogs are still in their natal burrows.

Do not use fumigants in burrows where nontarget species are thought to be present. Black-footed ferrets, burrowing owls, swift fox, cottontail rabbits, and several other species of wildlife occasionally inhabit prairie dog burrows and would likely be killed by fumigation. Be aware of sign and avoid fumigating burrows that are occupied by nontarget wildlife. Some manufacturers' labels now require private applicators to conduct black-footed ferret surveys before application. Detailed information on identifying black-footed ferrets and their sign is included in Appendix A of this chapter. Burrows used by burrowing owls often have feathers, pellets, and whitewash nearby. Natal burrows are often lined with finely shredded cow manure. Migratory burrowing owls usually arrive in the central Great Plains in late April and leave in early October. Fumigate before late April to minimize the threat to burrowing owls.

Aluminum Phosphide. Aluminum phosphide is a Restricted Use Pesticide, registered as a fumigant for the control of burrowing rodents. The tablets react with moisture in prairie dog burrows, and release toxic phosphine gas (PH_3). Use a 4-foot (1.2-m) section of 2-inch (5-cm) PVC pipe to improve placement of the tablets. Insert the pipe into a burrow and roll the tablets down the pipe. Place crumpled newspaper and/or a slice of sod in the burrow to prevent loose soil from smothering the tablets and tightly pack the burrow entrance with soil. To increase efficiency, work in pairs, one person dispensing and one plugging burrows.

Always wear cotton gloves while handling aluminum phosphide. Aim containers away from the face when opening and work into the wind to avoid inhaling phosphine gas from the container and the treated area. Aluminum phosphide should be stored in a well-ventilated area, never inside a vehicle or occupied building. Aluminum phosphide is classified as a flammable solid. Check with your local department of transportation for regulations regarding transportation of hazardous materials.

Aluminum phosphide can be purchased by certified pesticide applicators through national suppliers (see **Supplies and Materials**) or local retail distributors. It typically provides an 85% to 95% reduction in prairie dog populations when applied correctly and costs about $25 per acre ($63/ha) to apply. It is typically more cost-effective to use than gas cartridges because of the reduced handling time.

Gas Cartridges. Gas cartridges have been used for many years to control prairie dogs. When ignited, they burn and produce carbon monoxide, carbon dioxide, and other gases. To prepare a gas cartridge for use, insert a nail or small screwdriver in the end at marked points and stir the contents before inserting and lighting the fuse. Hold the cartridge away from you until it starts burning, then place it deep in a burrow. Burrows should be plugged immediately in the same way as with aluminum phosphide. Be careful when using gas cartridges because they can cause severe burns. Do not use them near flammable materials or inside buildings. Gas cartridges are a General Use Pesticide, available through USDA-APHIS-ADC. They provide up to 95% control when applied correctly and cost about $35 per acre ($88/ha) to apply.

Trapping

Cage traps can be used to capture individual animals, but the process is typically too expensive and time consuming to be employed for prairie dog control. Best results are obtained by trapping in early spring after snowmelt and before pasture green up. Bait traps with oats flavored with corn oil or anise oil.

It may be difficult to find release sites for prairie dogs. Releasing prairie dogs into an established colony will increase stress on resident and released prairie dogs.

Body-gripping traps, such as the Conibear® No. 110, are effective when placed in burrow entrances. No. 1 Gregerson snares can be used to remove a few prairie dogs, but the snares are usually rendered useless after each catch. Prairie dogs also can be snared by hand, using twine or monofilament line. These traps and snares may be effective for 1- to 5-acre (0.4- to 2-ha) colonies where time is not a consideration.

Shooting

Shooting is very selective and not hazardous to nontarget wildlife. It is most effective in spring because it can disrupt prairie dog breeding. Continuous shooting can remove 65% of the population during the year, but it usually is not practical or cost-effective. Prairie dogs often become wary and gun-shy after extended periods of shooting. They can be conditioned to loud noises by installing a propane cannon or old, mis-timed gasoline engine in the town for 3 to 4 days before shooting.

Long range, flat trajectory rifles are the most efficient for shooting prairie dogs. Rifles of .22 caliber or slightly larger are most commonly used. Bipods and portable shooting benches, telescopic sights, and spotting scopes are also useful equipment for efficient shooting. Contact a local extension office or state wildlife agency for lists of shooters and receptive landowners.

Other Methods

An amazing variety of home remedies have been tried in desperate attempts to control prairie dogs. Engine

exhaust, dry ice, butane, propane, gasoline, anhydrous ammonia, insecticides, nonregistered rodenticides, water, and dilute cement are all unregistered for prairie dog control. None have proven to be as cost-effective or successful as registered rodenticides, and most are hazardous to applicators and/or nontarget species. In addition, those methods that have been observed by the authors (exhaust, propane, ammonia, nonregistered rodenticides, and water) were substantially more expensive than registered and recommended methods.

A modified street sweeper vacuum has recently been used to suck prairie dogs out of their burrows. Inventor Gay Balfour of Cortez, Colorado, reports that the "Sucker Upper" can typically clear a range of 5 to 20 acres (2 to 8 ha) per day at a cost of $1,000 per day, not including travel expenses. This device, unfortunately, has not been independently tested. Although relatively expensive, this method may provide a nonlethal approach to dealing with prairie dogs where conventional methods are not appropriate or acceptable. The prairie dogs can either be euthanized with carbon dioxide gas or relocated if a suitable site can be found.

Integrated Pest Management

An integrated pest management approach dictates the timely use of a variety of cost-effective management options to reduce prairie dog damage to a tolerable level. We recommend the application of toxic bait in the fall, followed by the application of aluminum phosphide in the spring. If possible, defer grazing on the treated area during the next growing season to allow grasses and other vegetation to recover. A computer program was produced by Cox and Hygnstrom in 1993 to determine cost-effective options and economic returns of prairie dog control (see For Additional Information).

Economics of Damage and Control

Prairie dogs play an important role in the prairie ecosystem by creating islands of unique habitat that increase plant and animal diversity. Prairie dogs are a source of food for several predators and their burrows provide homes for several species, including the endangered black-footed ferret. Burrowing mixes soil types and incorporates organic matter, both of which may benefit soil. It also increases soil aeration and decreases compaction. Prairie dogs provide recreational opportunities for nature observers, photographers, and shooters. The presence of large, healthy prairie dog towns, however, is not always compatible with agriculture and other human land-use interests.

Prairie dogs feed on many of the same grasses and forbs that livestock do. Annual dietary overlap has been estimated from 64% to 90%. One cow and calf ingest about 900 pounds (485 kg) of forage per month during the summer (1 AUM). One prairie dog eats about 8 pounds (17.6 kg) of forage per month during the summer. At a conservative population density of 25 prairie dogs per acre (60/ha) and dietary overlap of 75%, it takes 6 acres (2.4/ha) of prairie dogs to equal 1 AUM. Small, rather widely dispersed colonies occupying 20 acres (8 ha) or less are tolerated by many landowners because of the sport hunting and aesthetic opportunities they provide. Colonies that grow larger than 20 acres (8 ha) often exceed tolerance levels because of lost AUMs, taxes, and increasing control costs.

The South Dakota Department of Agriculture (1981) reported that 730,000 acres (292,000 ha) were inhabited by prairie dogs in 1980, with a loss of $9,570,000 in production. The South Dakota livestock grazing industry similarly estimated losses of up to $10.29 per acre ($25.43/ha) on pasture and rangeland inhabited by prairie dogs and $30.00 per acre ($74.10/ha) for occupied hay land. Prairie dogs inhabited about 73,000 acres (29,200 ha) in Nebraska in 1987, with a loss estimated at $200,000. A reported 1/2 to 1 million acres (200,000 to 400,000 ha) are occupied in Colorado. A committee of the National Academy of Sciences (1970) concluded that "the numerous eradication campaigns against prairie dogs and other small mammals were formerly justified because of safety for human health and conflicts with livestock for forage."

On the other hand, Collins et al. (1984) found it was not economically feasible to treat prairie dogs on shortgrass rangeland with zinc phosphide in South Dakota because the annual control costs exceeded the value of forage gained. Seventeen acres (6.8 ha) would have to be treated to gain 1 AUM. Uresk (1985) reported that South Dakota prairie dog towns treated with zinc phosphide yielded no increase in production after 4 years. The cost-effectiveness of prairie dog control depends greatly on the age, density, and size of the prairie dog colony; soil and grassland type; rainfall; and control method employed.

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Figure 1 by Emily Oseas Routman.

Figure 2 by Dave Thornhill, University of Nebraska.

Figure 3 by Renee Lanik, University of Nebraska.

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Appendix A

BLACK-FOOTED FERRETS

Fig. 4. Black-footed ferret, *Mustela nigripes*

Introduction

The black-footed ferret (*Mustela nigripes,* Fig. 4) is the most rare and endangered mammal in North America. Black-footed ferrets establish their dens in prairie dog burrows and feed almost exclusively on prairie dogs. The reduction in prairie dog numbers in the last 100 years and the isolation and disappearance of many large towns has led to the decline of the ferret population. Large and healthy prairie dog towns are needed to ensure that black-footed ferrets survive in the wild.

Identification

Black-footed ferrets are members of the weasel family and are the only ferret native to North America. The most obvious distinguishing feature is the striking black mask across the face. The feet, legs, and tip of the tail are

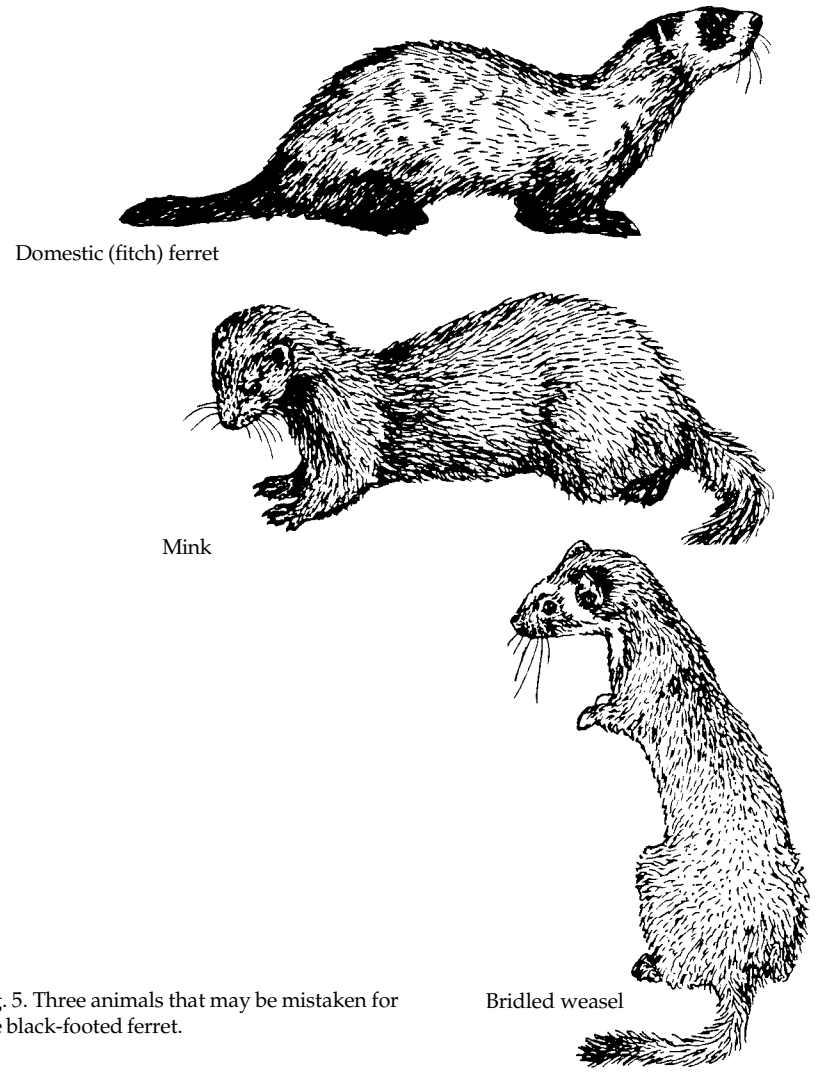

Fig. 5. Three animals that may be mistaken for the black-footed ferret.

also black. The remaining coat is pale yellow-brown, becoming lighter on the under parts of the body and nearly white on the forehead, muzzle, and throat. The top of the head and middle of the back are a darker brown. Ferrets have short legs, long, well-developed claws on the front paws, large pointed ears, and relatively large eyes.

Ferrets are similar in size and weight to wild mink. Adult male ferrets are 21 to 23 inches (53.3 to 58.4 cm) long and weigh 2 to 2 1/2 pounds (0.9 to 1.2 kg). Females are slightly smaller.

The native black-footed ferret may be confused with the domestic European fitch ferret, long-tailed weasel, bridled weasel, or wild mink (Fig. 5). The domestic fitch ferret has longer and darker pelage on the back, yellowish underfur, and an entirely black tail. The bridled weasel is a variant of the longtail weasel. It occurs in southwest Kansas, parts of Oklahoma, Texas, and New Mexico. The bridled weasel has a mask or dark markings on its face, but is smaller than a black-footed ferret. It does not have black feet, and it has a tail that is longer in relation to its total body length. Mink are about the same size as black-footed ferrets but are dark brown and occasionally have white markings on the throat.

Range

The original range of the black-footed ferret included most of the Great Plains area. Its current range within the Great Plains is unknown, although it is assumed to be greatly reduced from the original range. Currently the only known wild ferret population is an experimental population that has been released in north-central Wyoming. For the past 10 years, biologists have intensively searched for and investigated hundreds of reports of black-footed ferrets, but no new populations have been found. In addition, a public reward of $5,000 to $10,000 was available during the 1980s for sightings of black-footed ferrets, but none were confirmed. Current efforts are being made to identify black-footed ferret habitat and potential reproduction sites. Captive breeding populations are held at Wheatland, Wyoming, at the Wyoming Game and Fish Department's Sybille Conservation and Education Center, and at zoos in Omaha, Nebraska; Washington, DC; Louisville, Kentucky; Colorado Springs, Colorado; Phoenix, Arizona; and Toronto, Ontario.

Habitat

Black-footed ferrets rely on prairie dogs for both food and shelter. Therefore, all active prairie dog colonies are considered potential black-footed ferret habitat. Resident ferrets have only been found in prairie dog towns. Transient and dispersing ferrets may cross areas that are not occupied by prairie dogs.

General Biology, Reproduction, and Behavior

Normally 4 young ferrets are born per litter in May and June. The mother alone cares for the young and directs their activities until they disperse in mid-September. The young are first observed aboveground during daylight hours in July.

From June to mid-July, the ferret family remains in the same general area of the prairie dog town. Around the middle of July, after the young are active aboveground at night, the family extends its area of activity. By the middle of July the young ferrets are weaned at nearly one-half adult size.

By early August, the mother ferret separates the young and places them in different burrows. At this time some

of the young occasionally hunt at night by themselves. By mid-August, they can be seen during daylight hours, peering out of their burrow, playing near the entrance, and sometimes following the adult female.

By late August or early September, when the young are as large as the adult, the ferret family starts to disperse and is no longer seen as a closely knit group. The young ferrets are solitary during the late fall, winter, and early spring. In December, ferrets become active just after sunset and are active at least until midnight.

Legal Status

The black-footed ferret is classified as an endangered species and receives full protection under the Federal Endangered Species Act of 1973 (PL 93-205). The act, as amended, requires federal agencies to ensure that any action authorized, funded, or carried out by them is not likely to jeopardize the continued existence of a threatened or endangered species or their habitat. Regulations implementing Section 7 of the act require that federal agencies determine if any actions they propose "may affect" any threatened or endangered species. If it is determined that a proposed action "may affect," then the agency is required to request formal Section 7 consultation with the US Fish and Wildlife Service. Section 9 of the act prohibits any person (including the federal government) from the "taking" of a listed species. The term *take* means to harass, harm, pursue, hunt, shoot, wound, kill, capture, or collect, or to attempt to engage in any such conduct. Habitat destruction constitutes the taking of a listed species.

Guidelines for black-footed ferret searches have been developed by the US Fish and Wildlife Service (Black-footed Ferret Survey Guidelines for Compliance with the Endangered Species Act, 1989). Federal agencies are required by the US Fish and Wildlife Service to conduct black-footed ferret surveys if their proposed actions may affect ferrets or their habitat. Although encouraged to do so, private landowners and applicators are not required by law to conduct surveys unless their activities are associated with federal programs or if they are specifically directed by pesticide labels. Compliance with or disregard for black-footed ferret survey guidelines does not, of itself, show compliance with or violation of the Endangered Species Act or any derived regulations.

Guidelines for Black-footed Ferret Surveys

Any actions that kill prairie dogs or alter their habitat could prove detrimental to ferrets occupying affected prairie dog towns. The US Fish and Wildlife Service guidelines should assist agencies or their authorized representatives in designing surveys to "clear" prairie dog towns prior to initiation of construction projects, prairie dog control projects, or other actions that affect prairie dogs. If these guidelines are followed by individuals conducting black-footed ferret surveys, agency personnel can be reasonably confident in results that indicate black-footed ferrets are not occupying a proposed project area.

Delineation of Survey Areas. Until the time that wildlife agencies are able to identify reintroduction areas and to classify other areas as being free of ferrets, surveys for black-footed ferrets will usually be recommended. During this interim period the following approach is recommended to determine where surveys are needed.

A black-tailed prairie dog town or complex of less than 80 acres (32 ha) having no neighboring prairie dog towns may be developed or treated without a ferret survey. A neighboring prairie dog town is defined as one less than 4.3 miles (7 km) from the nearest edge of the town being affected by a project.

Black-tailed prairie dog towns or complexes greater than 80 acres (32 ha) but less than 1,000 acres (400 ha) may be cleared after a survey for black-footed ferrets has been completed, provided that no ferrets or ferret sign have been found.

A white-tailed prairie dog town or complex of less than 200 acres (81 ha) having no neighboring prairie dog towns may be cleared without a ferret survey. White-tailed prairie dog towns or complexes greater than 200 acres (81 ha) but less than 1,000 acres (400 ha), may be cleared after completion of a survey for black-footed ferrets, provided that no ferrets or their sign were found during the survey.

Contact the US Fish and Wildlife Service before any federally funded or permitted activities are conducted on black-tailed or white-tailed prairie dog towns or complexes greater than 1,000 acres, to determine the status of the area for future black-footed ferret reintroductions.

Defining a Prairie Dog Town/ Complex

For the purpose of this document a prairie dog town is defined as a group of prairie dog holes in which the density meets or exceeds 20 burrows per hectare (8 burrows/acre). Prairie dog holes need not be active to be counted but they should be recognizable and intact; that is, not caved in or filled with debris. A prairie dog complex consists of two or more neighboring prairie dog towns, each less than 4.3 miles (7 km) from the other.

Timing of Surveys

The US Fish and WIldlife Service recommends that surveys for black-footed ferrets be conducted as close to the initiation of a project construction date as possible but not more than 1 year before the start of a proposed action. This is recommended to minimize the chance that a ferret might move into an area during the period between completion of a survey and the start of a project.

Project Type

Construction projects (buildings, facilities, surface coal mines, transmission lines, major roadways, large pipelines, impoundments) that permanently alter prairie dog towns should be surveyed. Projects of a temporary nature and those that involve only minor disturbances (fences, some power lines,

underground cables) may be exempted from surveys when project activities are proposed on small prairie dog towns or complexes of less than 1,000 acres (400 ha), do not impact those areas where ferret sightings have been frequently reported, or occur on areas where no confirmed sightings have been made in the last 10 years.

The US Fish and Wildlife Service recommends that before any action involving the use of a toxicant in or near a prairie dog town begins, a survey for ferrets should be conducted. If toxicants or fumigants are to be used, and the town proposed for treatment is in a complex of less than 1,000 acres (400 ha), the town should be surveyed using the nocturnal survey technique 30 days or less before treatment. Prairie dog towns or complexes greater than 1,000 acres (400 ha) should not be poisoned without first contacting your local US Fish and Wildlife Service office.

Survey Methods

Method 1 — Daylight surveys for ferrets are recommended if surveys are conducted between December 1 and March 31. This type of survey is used to locate signs left by ferrets. During winter months, ferret scats, prairie dog skulls, and diggings are more abundant because prairie dogs are less active and less likely to disturb or destroy ferret sign. When there is snow cover, both ferret tracks and fresh diggings are more obvious and detectable.

Daylight searches for ferret sign should meet the following criteria to fulfill the minimum standards of these guidelines:

1. Three searches must be made on each town. Conduct each search when fresh snow has been present for at least 24 hours and after 10 or more days have passed between each search period.
2. Vehicles driven at less than 5 miles per hour (8.3 km/hr) may be used to search for tracks or ferret diggings, but complete visual inspections of each part of the town being surveyed is required (that is, visually overlapping transects).
3. If ferret sign is observed, photograph the sign and make drawings and measurements of diggings before contacting the US Fish and Wildlife Service and state wildlife agency.

Method 2 — Nighttime surveys involve the use of spotlighting techniques for locating ferrets. This survey method is designed to locate ferrets when the maximum population and the longest periods of ferret activity are expected to occur.

Minimum standards should be followed as recommended below:

1. Conduct surveys between July 1 and October 31.
2. Continuously survey the prairie dog town using spotlights. Begin surveys at dusk and continue until dawn on each of at least 3 consecutive nights. Divide large prairie dog colonies into tracts of 320 acres (130 ha) and search each tract systematically throughout 3 consecutive nights. Rough uneven terrain and tall dense vegetation may require smaller tracts to result in effective coverage of a town.
3. Begin observations on each prairie dog town or tract at a different starting point on each successive night to maximize the chance of overlapping nighttime activity periods of ferrets.
4. A survey crew should consist of one vehicle and two observers equipped with two 200,000 to 300,000 candlepower (lumen) spotlights. In terrain not suitable for vehicles, a crew should consist of two individuals working on foot with battery-powered 200,000 to 300,000 candlepower (lumen) spotlights. To estimate the number of crew nights for a survey, divide the total area of prairie dog town to be surveyed by 320 acres (130 km) and multiply by 3. One or both of the observers in each survey crew should be a biologist trained in ferret search techniques.

Additional information on data collection, reporting, and training workshops are included in *Black-footed Ferret Survey Guidelines for Compliance with the Endangered Species Act, 1989*, available from the US Fish and Wildlife Service.

Black-footed Ferret Sign

To determine if black-footed ferrets are living in a given area, some sign must be found or a ferret observed. Evidence such as tracks, diggings, or droppings is uncommon, even where ferrets occur. They are secretive, nocturnal, and inactive for long periods of time, and therefore are very seldom seen by people.

Prairie dogs compact the soil around their burrows, making it difficult to find ferret tracks. Most ferret tracks are observed when snow covers the ground. The average distance between each "twin print" track in the normal bounding gait is 12 to 16 inches (30.5 to 40.6 cm) (Fig. 6). The track of a ferret is very similar to that of a mink or weasel. In Wyoming, ferrets are most active between December and early March, sometimes covering up to 5 miles (8 km) per night. Scent marks, scrapes, and scratches in the snow may be noticeable. Ferret droppings are rarely found above ground. They are long and thin, taper on both ends, and consist almost entirely of prairie dog hair and bones.

Ferrets sometimes form "trenches" or "ramps" when they excavate prairie dog burrows. Prairie dogs occasionally plug the entrances to their burrow systems with soil. When excavating such a plug in a burrow, the ferret backs out with the soil held against its chest with its front paws. It generally comes out of the burrow in the same path each time. This usually occurs when snow covers the ground. After repeated trips, a ramp from 3 to 5 inches (7.6 to 12.7 cm) wide and from 1 to 9 feet (0.3 to 2.7m) long is formed (Fig. 7). Badgers, foxes, and weasels occasionally form similar ramps.

Prairie dogs generally deposit excavated soil around the burrow entrance to form a mound, building it higher by

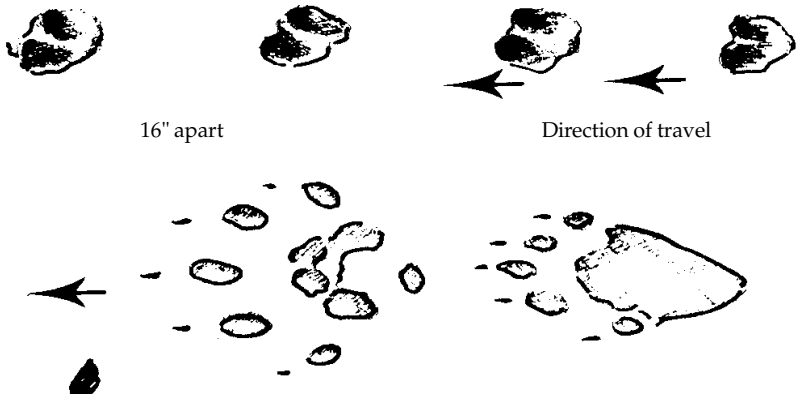

Fig. 6. Black-footed ferret tracks left in the snow.

Fig. 7. Ramp made by a black-footed ferret excavating a prairie dog burrow.

adding soil from outside the mound. The movement of soil toward the mound is in the opposite direction of that done by a ferret.

Ferrets sometimes dig in fresh snow. These "snow trenches" are narrow trough-like depressions in the snow that extend away from prairie dog burrow entrances. Snow trenches are relatively rare compared to trenches in the soil.

If you observe a black-footed ferret or identify ferret sign while conducting surveys, notify your local US Fish and Wildlife Service or state wildlife representative within 24 hours.

Acknowledgments

Figures 4 and 5 by Emily Oseas Routman.

Figure 6 courtesy of Thomas M. Campbell III, Biota Research and Consulting Service.

Figure 7 courtesy of Walt Kittams.

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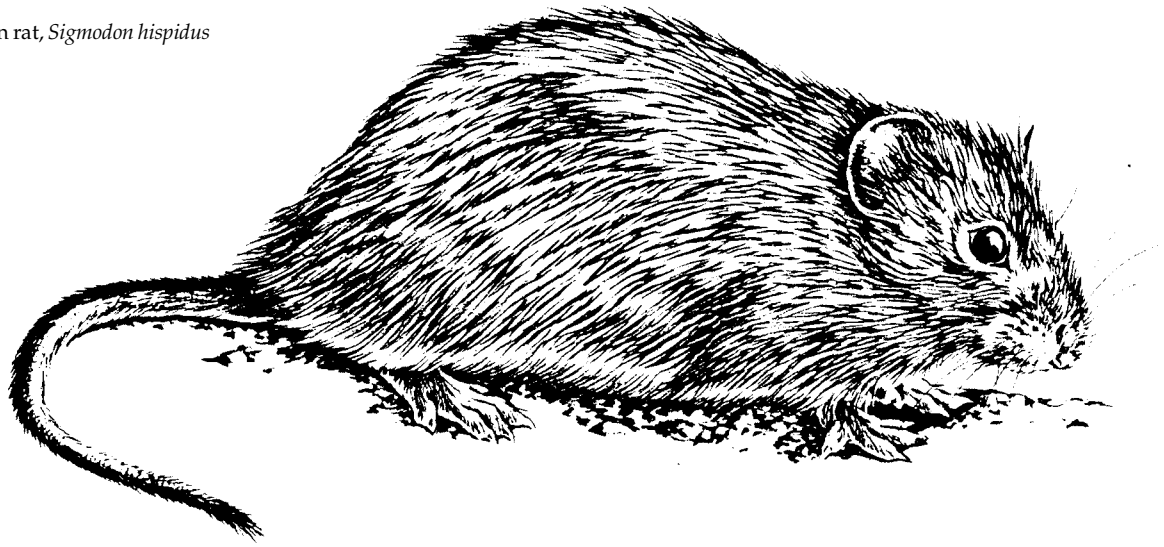
Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Donald W. Hawthorne
Associate Deputy Administrator
USDA-APHIS-
Animal Damage Control
Washington, DC 20090

COTTON RATS

Fig. 1. Hispid cotton rat, *Sigmodon hispidus*



Damage Prevention and Control Methods

Exclusion

Usually not practical.

Cultural Methods

Remove dense vegetation.

Repellents

Not effective.

Toxicants

2% zinc phosphide on dry bait.

Fumigants

Not practical.

Trapping

Snap traps (rat traps).

Live traps.

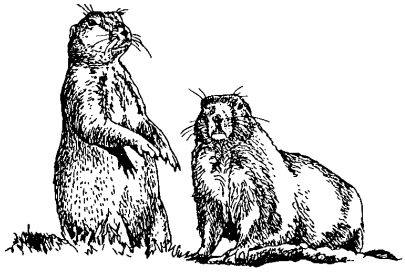
Shooting

Not practical.

Identification

The hispid cotton rat *(Sigmodon hispidus)* is a moderately large, robust rodent with a scaly, sparsely haired tail that is shorter than the combined head and body.

Cotton rats have relatively large eyes. The ears are large but almost hidden in the fur. They have four toes and a small thumb on their front feet and five toes on each hind foot. The cotton rat has very small internal cheek pouches. Distinguishing characteristics are the rough grizzled appearance of the blackish or grayish fur and the rather stiff black guard hairs.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

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This rodent has a high "Roman" nose and color similar to that of a javelina, resulting in the name "javelina rat" in many areas.

The total length averages 10 inches (25 cm) including the tail length of 4 inches (10 cm). The cotton rat may be distinguished from the Norway rat by its smaller size, shorter tail, and longer grizzled fur. Evidence of cotton rat presence are stem and grass cuttings 2 or 3 inches (5 or 8 cm) in length piled at various locations along runways, which are 3 to 5 inches (8 to 13 cm) wide. Pale greenish or yellow droppings, about 3/8 inch (9 mm) in length and 3/16 inch (5 mm) in diameter, may also be present along the runways.

Fig. 2. Range of the hispid cotton rat in North America.

Range

The hispid cotton rat occurs over most of the southern United States, from the southeastern tip of California, southern Arizona and New Mexico, north to eastern Colorado, eastward through the southern portions of Kansas and Missouri, through Tennessee and North Carolina, and southward along the Atlantic coast through Florida, the Gulf states, and up the Rio Grande Valley (Fig. 2).

Two other species of cotton rat, the least cotton rat *(S. minimus)* and the yellownose cotton rat *(S. ochrognathus)*, occur only in small areas of southeastern Arizona and southwestern New Mexico. They are very similar to the hispid cotton rat.

Habitat

Cotton rats prefer dense cover such as grassy fields, overgrown roadsides, or fencerow vegetation adjacent to cultivated fields. They also occupy meadows, marshy areas, cactus patches, and weedy ditch banks. Under the protective cover, the cotton rat will have well-defined runways radiating in all directions from the nest site.

Food Habits

Cotton rats are normally herbivores, eating the roots, stems, leaves, and seeds of a wide variety of plants. They also feed on sugarcane, fruits, berries, and nuts. Cotton rats will cut tall plants off at the base and continue to cut them into shorter sections. They also eat insects, the eggs and young of ground-nesting birds (particularly quail), and the carcasses of dead animals.

General Biology, Reproduction, and Behavior

Cotton rats are basically nocturnal but will venture out in the daytime and are active year-round. The home range is small — from 1/4 to 3/4 acre (0.1 to 0.3 ha) for females and 1 to 1 1/4 acres (0.4 to 0.5 ha) for males. Cotton rats do not store food or hibernate. They can swim and do not hesitate to do so. This species is excitable, pugnacious, and aggressive toward mice living in the same fields. Their nests are a crude mass of dry grass fibers stripped from larger plant stems, placed in shallow surface depressions, among clumps of coarse grasses, underground in shallow tunnels, or under rocks or logs.

The species is very prolific and will breed throughout the year. Several litters may be produced annually, averaging 2 to 15 young per litter. The gestation period is 27 days, and the young are weaned in 10 to 15 days. Most young breed for the first time at 2 to 3 months of age. Therefore, several generations may live in the same nest at one time. The average life span is 6 months.

Damage

Cotton rat populations fluctuate greatly, ranging from 11 to 149 per acre (28 to 373/ha), and cause the most serious damage during population peaks. They may damage a variety of crops, including alfalfa, grains, grasses, vegetables, peanuts, fruit crops, sweet potatoes, and sugar beets. Cotton rats are especially troublesome in sugarcane and melons. Since these animals will eat quail eggs, a high cotton rat population may have a detrimental impact on quail nesting success. Cotton rats also compete with quail for the same foods.

Legal Status

Cotton rats are not protected in most states; some states classify them as nongame mammals. They may be taken if causing damage. Check local and state laws before beginning control measures.

Damage Prevention and Control Methods

Exclusion

If the area is small or the crop to be protected is of high value, a sheet-metal barrier 18 inches (46 cm) tall may be used to exclude cotton rats. Bury the barrier about 6 inches (15 cm) to prevent cotton rats from burrowing under it.

Cultural Methods

Remove dense cover by burning, mowing, plowing, or the use of herbicides to reduce habitat and prevent large population increases. Habitat modification is best as a preventive measure, since this control method will have little effect on the ensuing damage once a population reaches its peak.

Repellents

None are registered for repelling cotton rats.

Toxicants

Only zinc phosphide (2% active ingredient) is currently registered and being marketed for cotton rat control, and its use is limited to sugarcane fields. When applying toxic bait, lightly scatter teaspoon quantities in the rats' runways at 12- to 30-foot (3.6- to 9-m) intervals according to label instructions.

Fumigants

Fumigants are not very practical because cotton rats use their burrows and tunnels infrequently. Since state pesticide registrations vary, check with the local extension office or state wildlife agency for information on repellents, toxicants, and fumigants in your area.

Trapping

Small rodent live traps or rat-sized snap traps are effective for catching a small number of animals. The traps should be baited with a mixture of peanut butter and oatmeal or a piece of fresh carrot or sweet potato. The trap should be set in the runway at a right angle to the direction of travel.

Economics of Damage and Control

The amount and extent of damage is directly related to the relative density of the cotton rat population. The cost of control must be weighed against the value of the crop to be protected, such as sugarcane or melons.

Acknowledgments

Figures 1 and 2 from Schwartz and Schwartz (1981), adapted by Jill Sack Johnson.

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Editors
Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Volney W. Howard, Jr.
Professor of Wildlife Science
Department of Fishery and
Wildlife Sciences
New Mexico State University
Las Cruces, New Mexico 88003

KANGAROO RATS

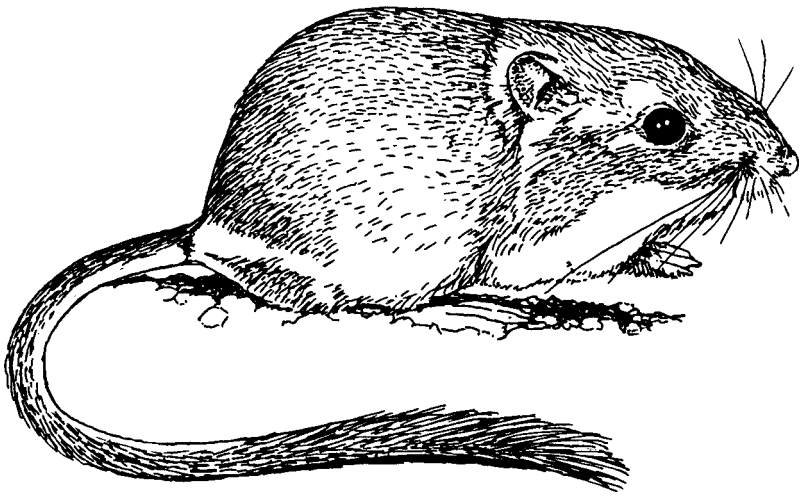


Fig. 1. The Ord's kangaroo rat, *Dipodomys ordi*

Damage Prevention and Control Methods

Exclusion

Rat-proof fences may be practical only for small areas of high-value crops.

Cultural Methods

Plant less palatable crops along field edges and encourage dense stands of rangeland grass.

Repellents

None are registered.

Toxicants

Zinc phosphide.

Fumigants

Aluminum phosphide and gas cartridges are registered for various burrowing rodents.

Trapping

Live traps.

Snap traps.

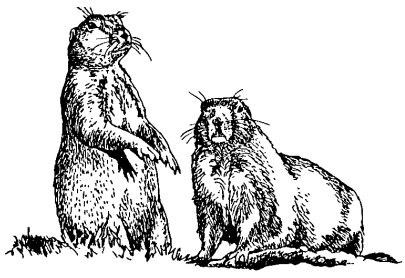
Other Methods

Use water to flush kangaroo rats from burrows.

Identification and Range

There are 23 species of kangaroo rats (genus *Dipodomys*) in North America. Fourteen species occur in the lower 48 states. The Ord's kangaroo rat (*D. ordi,* Fig. 1) occurs in 17 US states, Canada, and Mexico. Other widespread species include the Merriam kangaroo rat (*D. merriami*), bannertail kangaroo rat (*D. spectabilis*), desert kangaroo rat (*D. deserti*), and Great Basin kangaroo rat (*D. microps*).

Kangaroo rats are distinctive rodents with small forelegs; long, powerful hind legs; long, tufted tails; and a pair of external, fur-lined cheek pouches similar to those of pocket gophers. They vary from pale cinnamon buff to a dark gray on the back with pure white underparts and dark markings



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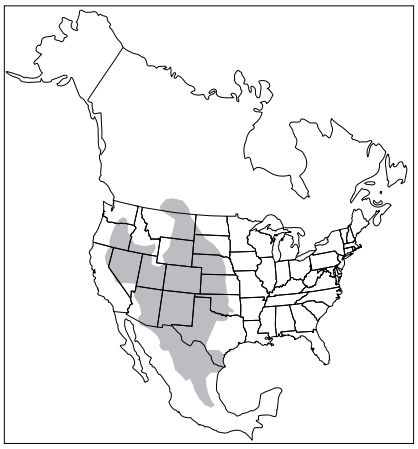

Fig. 2. Distribution of Ord's kangaroo rats in North America.

on the face and tail. The largest, the giant kangaroo rat (*D. ingens*), has a head and body about 6 inches (15 cm) long with a tail about 8 inches (20 cm) long. The bannertail kangaroo rat is approximately the same size, but has a white-tipped tail. The other common species of kangaroo rats are smaller. The Ord's kangaroo rat has a head and body about 4 inches (10 cm) long and a tail about 7 inches (18 cm) long.

Habitat

Kangaroo rats inhabit semiarid and arid regions throughout most of the western and plains states. The Ord's kangaroo rat is the most common and widespread of the kangaroo rats (Fig. 2). Several other species are located in Mexico, California, and the southwestern United States. They generally are not found in irrigated pastures or crops, but may be found adjacent to these areas on native rangelands, especially on sandy or soft soils. They also invade croplands under minimum tillage in these areas, particularly areas under dry farming.

Food Habits

Kangaroo rats are primarily seed eaters, but occasionally they will eat the vegetative parts of plants. At certain times of the year they may eat insects. They have a strong hoarding habit and will gather large numbers of seeds in their cheek pouches and take them to their burrows for storage. This caching activity can cause significant impact on rangeland and cropland. They remove seeds from a large area, thus preventing germination of plants, particularly grasses, in succeeding years. Since these rodents do not hibernate, the seed caches are a source of food during severe winter storms or unusually hot summer weather. Kangaroo rats are quite sensitive to extremes in temperature and during inclement weather may remain underground for several days.

General Biology, Reproduction, and Behavior

Kangaroo rats breed from February to October in southern desert states. The breeding period is shorter in the northern states. The gestation period is approximately 30 days. Reproductive rates vary according to species, food availability, and density of rodent populations. Females have 1 to 3 litters of 1 to 6 young per year. The young are born hairless and blind in a fur-lined nest within the tunnel system. Usually, the young remain in the nest and tunnel for nearly a month before appearing aboveground.

Only a few females will breed after a prolonged drought when food is in short supply. Most females will bear young when food is abundant, and some young females born early in the season will also produce litters before the season ends.

All kangaroo rats build tunnels in sandy or soft soil. The tunnel system is fairly intricate, and consists of several sleeping, living, and food storage chambers. The extensive burrowing results in a fair amount of soil being brought up and mounded on the ground surface. These mounds can be mistaken for prairie dog mounds, particularly when observed on aerial photographs. They may vary in size but can be as large as 15 feet (4.5 m) across and up to 2 feet (60 cm) high.

Kangaroo rats are completely nocturnal and often plug their burrow entrances with soil during the day to maintain a more constant temperature and relative humidity. They are often seen on roads at night, hopping in front of headlights in areas where they occur.

Kangaroo rats often occur in aggregations or colonies, but there appears to be little if any social organization among them. Burrows are spaced to allow for adequate food sources within normal travel distances. Spacing of mounds will vary according to abundance of food, but well-defined travel lanes have been observed between neighboring mounds.

When kangaroo rats are locally abundant, their mounds, burrow openings, and trails in vegetation and sand are conspicuous features of the terrain. Both the number of burrows and individuals per acre (ha) can vary greatly depending on locality and time of year. There are usually many more burrow openings than there are rats. Each active burrow system, however, will contain at least one adult rat. There could be as many as 35 rats per acre (14/ha) in farmlands. In rangelands, 10 to 12 rats per acre (4 to 5/ha) is more likely. Kangaroo rats do not have large home ranges; their radius of activity is commonly 200 to 300 feet (60 to 90 m), rarely exceeding 600 feet (183 m). They may move nearly a mile (1.6 km) to establish a new home range.

Damage and Damage Identification

Historically, kangaroo rats were considered to be of relatively minor economic importance. They have come into direct conflict with human interests, however, with large-scale development of sandy soil areas for sprinkler-irrigated corn and alfalfa production. A primary conflict develops at planting time when kangaroo rats dig up newly planted seeds and clip off new sprouts at their base. Damage is more severe when population densities are high. Smaller populations apparently are able to subsist on waste grain and damage is not as apparent. Since kangaroo rats are

primarily seed eaters, they find irrigated fields and pastures a veritable oasis and feed extensively on waste grain after harvest.

Kangaroo rats have foiled attempts to restore overused rangelands. Their habit of collecting and caching large numbers of grass seeds restricts the natural reseeding process. In semiarid rangelands, activities of kangaroo rats can prevent an area from making any appreciable recovery even though the area received complete rest from livestock grazing for 5 years or more. Reducing livestock grazing is not enough. As long as kangaroo rats remain in an area, they will restrict the reestablishment of desirable forages, particularly native grasses.

Legal Status

Most kangaroo rats are considered nongame animals and are not protected by state game laws. Certain local subspecies may be protected by regulations regarding threatened and endangered species. Consult local authorities to determine their legal status before applying controls.

Attention!! Five kangaroo rat species currently are listed as endangered by the US Fish and Wildlife Service. They are found mostly in California and include the Fresno kangaroo rat (*D. nitratoides exilis*), giant kangaroo rat (*D. ingens*), Morro Bay kangaroo rat (*D. heermanni morroensis*), Stephens' kangaroo rat (*D. stephensi* including *D. cascus*), and Tipton kangaroo rat (*D. nitratoides nitratoides*). Persons working in California, southern Oregon, south central Nevada, and western Arizona should have expertise in identifying these species, their mounds, and the ranges in which they likely occur.

Damage Prevention and Control

Exclusion

Exclusion is most often accomplished by the construction of rat-proof fences and gates around the area to be protected. Most kangaroo rats can be excluded by 1/2-inch (1.3-cm) mesh hardware cloth, 30 to 36 inches (75 to 90 cm) high. The bottom 6 inches (15 cm) should be turned outward and buried at least 12 inches (30 cm) in the ground. Exclusion may be practical for small areas of high-value crops, such as gardens, but is impractical and too expensive for larger acreages.

Cultural Methods

Alfalfa, corn, sorghum, and other grains are the most likely crops to be damaged by kangaroo rats. When possible, planting should be done in early spring before kangaroo rats become active to prevent loss of seeds. Less palatable crops should be planted along field edges that are near areas infested with kangaroo rats.

High kangaroo rat numbers most often occur on rangelands that have been subjected to overuse by livestock. Kangaroo rats usually are not abundant where rangelands have a good grass cover, since many of the forbs that provide seeds for food are not abundant in dense stands of grass. Thus, changes in grazing practices accompanied by control programs may be necessary for substantial, long-term relief.

Repellents

There are no registered repellents for kangaroo rats.

Toxicants

Zinc Phosphide. At present, 2% zinc phosphide bait is federally registered for the control of the bannertail, Merriam, and Ord's kangaroo rats in rangeland vegetation and noncrop areas. Some states may also have Special Local Needs 24(c) registrations for zinc phosphide baits to control kangaroo rats.

Zinc phosphide pelleted rodent bait was tested on kangaroo rats in New Mexico (Howard and Bodenchuk 1984). Levels of control were much lower than those for 0.5% strychnine oats, but higher than for 0.16% strychnine oats. Zinc phosphide applied in June produced the highest percentage of control. Zinc phosphide is advantageous because it is thought to present little or no hazard of secondary poisoning to small canids and a low hazard to other nontarget wildlife.

Carefully read and follow all label instructions. Zinc phosphide is a Restricted Use Pesticide for retail sale to and use by certified applicators or persons under their direct supervision, and only for those uses covered by the applicator's certification.

Fumigants

There are no fumigants registered specifically for kangaroo rats. Aluminum phosphide and gas cartridges are currently registered for "burrowing rodents such as woodchucks, prairie dogs, gophers, and ground squirrels."

Trapping

Live Traps. Trapping with box-type (wire cage) traps can be successful in a small area when a small number of kangaroo rats are causing problems. These traps can be baited successfully with various grains, oatmeal, oatmeal and peanut butter, and other baits. One problem is the disposal of kangaroo rats after they have been trapped. They usually die from exposure if they remain in the trap for over 6 hours. If the rats are released, they should be taken to an area more than 1 mile (1.6 km) from the problem site. The release site should provide suitable habitat and be acceptable to everyone involved. Do not release kangaroo rats in areas where landowners do not want them.

Snap Traps. Trapping with snap traps is probably the most efficient and humane method for kangaroo rats. Mouse traps will suffice for smaller animals, but Victor® "museum specials" or rat traps are needed for larger kangaroo rats, particularly the bannertail. Successful baits include whole kernel corn, peanut butter and oatmeal, and oatmeal paste, which are placed on the trigger mechanism. Place traps near, but not inside, the burrow entrances or along runways between mounds. Check traps each day to remove dead kangaroo rats. Reset tripped traps and replace baits that

may have been removed by ants or other insects. Do not use whole kernel corn when large numbers of seed-eating songbirds are in the area.

Other Methods

If kangaroo rats from only one or two mounds are causing the problems, and water is available, they may be flushed from their burrows and either killed or allowed to go elsewhere. Collapse the mounds after the kangaroo rats have been driven out. This not only levels the surface but also allows you to detect burrow reinvasion by other kangarooa rats. Use caution when flushing burrows with water or trapping kangaroo rats. The burrow entrances are sometimes used by rattlesnakes seeking to escape heat and direct sunlight during hot days. Even on warm days, rattlesnakes may be found near mounds since kangaroo rats are a source of food for them.

Economics of Damage and Control

Wood (1969) found that Ord's kangaroo rats eat about 1,300 pounds (585 kg) of air-dried plant material per section per year in south central New Mexico based on average (medium) densities. He also reported an additional 336 pounds (151 kg) of air-dried plant material per section per year consumed by bannertail kangaroo rats in the same area under average (medium) population densities. These data were for arid rangelands and could be higher if the populations of either species were denser. This forage loss (3 Animal Unit Months [AUMs]) is currently valued at $6 to $12 per section in New Mexico.

Bannertail kangaroo rats stored 2.9 tons (2.6 mt) of plant material per section per year in their burrows. Furthermore, production of grasses on rangelands in excellent condition were reduced by 10.6% (or 12 AUMs) by denuding of areas in the vicinity of kangaroo rat mounds. These estimates do not include the loss of regeneration of desirable grasses due to seed consumption.

In areas that are being farmed for production of pasture or commercial crops, densities of kangaroo rats could become much higher than those reported by Wood (1969). These higher densities, coupled with higher crop values, could conceivably produce losses greater than $100 per acre ($250/ha).

The cost of controlling kangaroo rats can be quite high if labor-intensive methods are employed. Of course, the cost per mound will be higher when controlling a few mounds rather than larger numbers. Trapping is the most costly method; toxicants the least costly. The cost of the traps varies greatly, depending on the size, number, and kind of traps used. Live traps cost more than snap traps. The cost of toxic baits is relatively low on a per-mound basis. Labor costs are reduced when large areas are treated with toxic grain baits using a four-wheel, all-terrain cycle.

Information on specific control techniques and limitations can be obtained from your local extension agent or extension wildlife specialist. In addition, personnel from state wildlife agencies or USDA-APHIS-ADC can provide information on control measures available in your area.

Acknowledgments

Figure 1 by Emily Oseas Routman.

Figure 2 adapted by the author from Burt and Grossenheider (1976).

For Additional Information

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Editors
Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Robert M. Timm
Superintendent and Extension
Wildlife Specialist
Hopland Research and
Extension Center
University of California
Hopland, California 95449

NORWAY RATS

Fig. 1. Norway rat, *Rattus norvegicus*

Damage Prevention and Control Methods

Exclusion

Seal all openings larger than 1/2 inch (1.3 cm) wide.

Habitat Modification

Good sanitation practices reduce sources of food, water, and shelter.

Store foodstuffs in rodent-proof structures or containers.

Store and dispose of refuse and garbage properly.

Control weeds and remove debris from around structures.

Frightening

Ultrasonic devices have not been proven to control rats.

Repellents

Ro-pel®.

Toxicants

Anticoagulant rodenticides (slow-acting chronic-type toxicants)
Brodifacoum (Talon®).
Bromadiolone (Maki®, Contrac®).
Chlorophacinone (RoZol®).
Diphacinone (Ramik®, Ditrac®).
Pindone (Pival®, Pivalyn®)
Warfarin (Final® and others).

Toxicants other than anticoagulants (may be acute or chronic toxicants)
Bromethalin (Assault®, Vengeance®).
Cholecalciferol (Quintox®).
Red Squill.
Zinc phosphide (Ridall Zinc®, ZP® rodent bait).

Fumigants

In some situations, outdoor burrow fumigation may be effective.
Aluminum phosphide (Phostoxin® and others).
Chloropicrin.
Gas cartridges.
Methyl bromide.

Trapping

Snap traps.

Live traps.

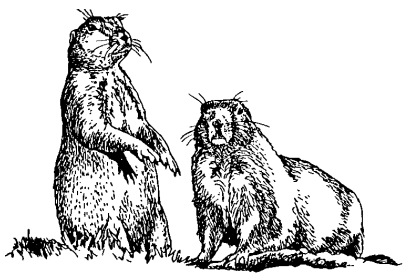
Glue boards.

Other Methods

Clubbing.

Shooting.

Dogs and cats are of limited value in some situations.



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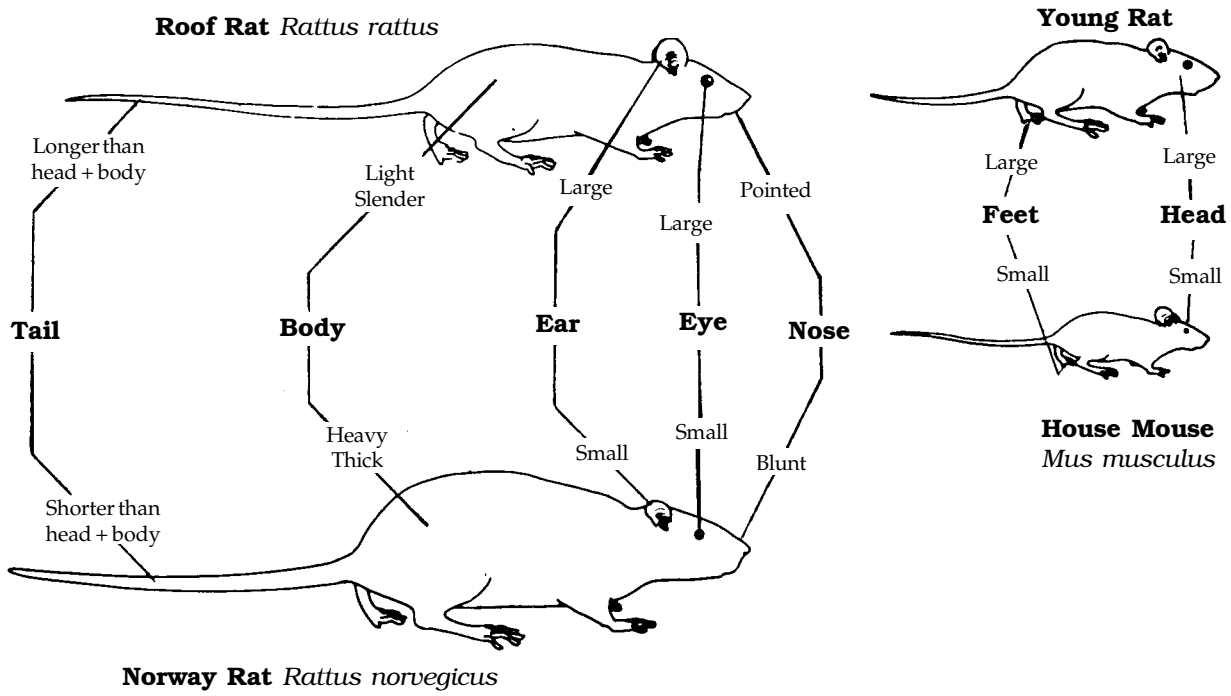


Fig. 2. Characteristics of commensal rodents

Identification

The Norway rat (*Rattus norvegicus*, Fig. 1) is a stocky burrowing rodent, unintentionally introduced into North America by settlers who arrived on ships from Europe. Also called the brown rat, house rat, barn rat, sewer rat, gray rat, or wharf rat, it is a slightly larger animal than the roof rat (Fig. 2). Adult Norway rats weigh an average of 1 pound (454 g). Their fur is coarse and usually brownish or reddish gray above and whitish gray on the belly. Blackish individuals occur in some locations.

Range

First introduced into the United States around 1775, the Norway rat has now spread throughout the contiguous 48 states. It is generally found at lower elevations but may occur wherever humans live.

Habitat

Norway rats live in close association with people. In urban or suburban areas they live in and around residences, in cellars, warehouses, stores, slaughterhouses, docks, and in sewers. On farms they may inhabit barns, granaries, livestock buildings, silos, and kennels.

They may burrow to make nests under buildings and other structures, beneath concrete slabs, along stream banks, around ponds, in garbage dumps, and at other locations where suitable food, water, and shelter are present. Although they can climb, Norway rats tend to inhabit the lower floors of multistory buildings.

Food Habits

Norway rats will eat nearly any type of food. When given a choice, they select a nutritionally balanced diet, choosing fresh, wholesome items over stale or contaminated foods. They prefer cereal grains, meats and fish, nuts, and some types of fruit. Rats require 1/2 to 1 ounce (15 to 30 ml) of water daily when feeding on dry foods but need less when moist foods are available. Food items in household garbage offer a fairly balanced diet and also satisfy their moisture needs.

General Biology, Reproduction, and Behavior

Norway rats are primarily nocturnal. They usually become active about dusk, when they begin to seek food and water. Some individuals may be active during daylight hours when rat populations are high.

Rats have poor eyesight, relying more on their hearing and their excellent senses of smell, taste, and touch. They are considered color-blind. Therefore, for safety reasons, baits can be dyed distinctive colors without causing avoidance by rats, as long as the dye does not have an objectionable taste or odor.

Rats use their keen sense of smell to locate food items and to recognize

other rats. Their sense of taste is excellent, and they can detect some contaminants in their food at levels as low as 0.5 parts per million.

Norway rats usually construct nests in below-ground burrows or at ground level (Fig. 3). Nests may be lined with shredded paper, cloth, or other fibrous material. Litters of 6 to 12 young are born 21 to 23 days after conception. Newborn rats are hairless and their eyes are closed, but they grow rapidly. They can eat solid food at 2 1/2 to 3 weeks. They become completely independent at about 3 to 4 weeks and reach reproductive maturity at 3 months of age.

Females may come into heat every 4 or 5 days, and they may mate within a day or two after a litter is born. Breeding often peaks in spring and fall, with reproductive activity declining during the heat of summer and often stopping completely in winter, depending on habitat. These seasonal trends are most pronounced in more severe climates. The average female rat has 4 to 6 litters per year and may successfully wean 20 or more offspring annually.

Norway rats have physical capabilities that enable them to gain entry to structures by gnawing, climbing, jumping, swimming, and other tactics. For more detailed information on their physical abilities and the resulting need to design rodent-proof structures, see the chapter **Rodent-Proof Construction and Exclusion Methods.**

Studies indicate that during its daily activities, a rat normally travels an area averaging 100 to 150 feet (30 to 45 m) in diameter. Rats seldom travel farther than 300 feet (100 m) from their burrows to obtain food or water.

Rats constantly explore and learn about their environment, memorizing the locations of pathways, obstacles, food and water, shelter, and other elements in their domain. They quickly detect and tend to avoid new objects placed into a familiar environment. Thus, objects such as traps and bait stations often are avoided for several days or more following their initial placement. Place baits and bait stations near, but not on, rat runways. Rats will quickly find them and after a short period of avoidance, will cautiously investigate them. Baited but unset traps will aid in overcoming rats' fear of them; expanded-trigger traps set directly on travel routes may immediately catch rats.

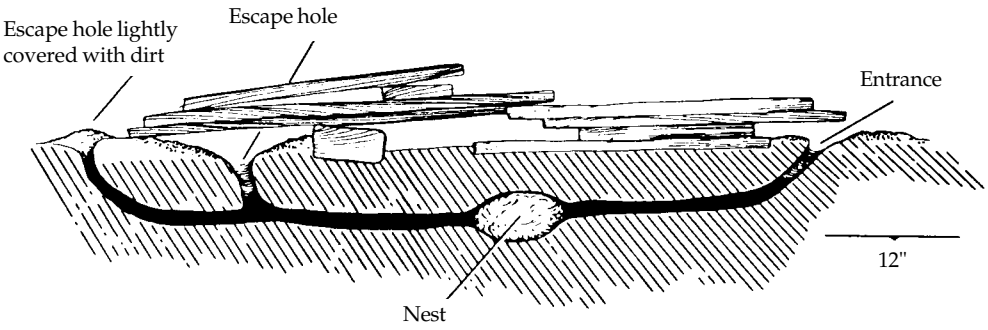


Fig. 3. Norway rat burrow system beneath a pile of boards.

Rats will at first avoid novel food items placed in their environment. They may eat very small amounts, and subsequent feeding will depend on the flavor of the food and its physiological effect. If the food contains poison or some other substance that soon produces an ill effect but not death, the food will often be associated with the illness. This "bait shyness" was a major problems when single-dose acute toxicants were the main rodenticides in use. Today, only two rodenticides registered for Norway rat control, red squill and zinc phosphide, possess characteristics that make bait shyness a potential problem.

Bait shyness can persist for weeks or months and may be transferred to nontoxic foods of similar types. Prebaiting, that is, training rats to feed repeatedly on nontoxic bait for a period of days prior to applying the toxicant in the bait, will largely prevent sublethal doses and thus bait shyness. It will also lead to successful control, with very few rats left to become bait-shy. Prebaiting will almost always increase control success when zinc phosphide or red squill baits are used.

Because anticoagulant rodenticides are slow-acting, the rats' subsequent illness is not associated with the bait even if a sublethal dose is consumed; thus, bait shyness does not usually occur. These baits serve, in effect, as their own prebait.

Damage and Damage Identification

Norway rats consume and contaminate foodstuffs and animal feed. They may damage crops in fields prior to and during harvest, and during processing and storage. Rats also damage containers and packaging materials in which foods and feed are stored.

Rats cause structural damage to buildings by burrowing and gnawing. They undermine building foundations and slabs, cause settling in roads and railroad track beds, and damage the banks of irrigation canals and levees. Rats also may gnaw on electrical wires or water pipes, either in structures or below ground. They damage structures further by gnawing openings through doors, window sills, walls, ceilings, and floors. Considerable damage to insulated structures can occur as a result of rat burrowing and nesting in walls and attics.

Among the diseases rats may transmit to humans or livestock are murine typhus, leptospirosis, trichinosis, salmonellosis (food poisoning), and ratbite fever. Plague is a disease that can be carried by a variety of rodents, but it is more commonly associated with roof rats (*Rattus rattus*) than with Norway rats.

Rat Sign

The presence of rats can be determined by a number of signs described below:

Droppings may be found along runways, in feeding areas, and near shelter. They may be as large as 3/4 inch (2 cm) long and 1/4 inch (0.6 cm) in diameter. Fresh droppings are soft in texture.

Tracks, including footprints or tail marks, may be seen on dusty surfaces or in mud (Fig. 4). A tracking patch made of flour can be placed in pathways overnight to determine if rodents are present.

Urine, both wet and dry, will fluoresce under ultraviolet light. Urine stains may occur along travelways or in feeding areas.

Runs or burrows may be found next to walls, along fences, next to buildings, or under bushes and debris. Rats memorize pathways and use the same routes habitually.

Smudge marks (rub marks) may occur on beams, rafters, pipes, and walls as a result of oil and dirt rubbing off rats' fur along frequently traveled routes (Fig. 5).

Gnawing may be visible on doors, ledges, in corners, in wall material, on stored materials, or other surfaces wherever rats are present. Fresh accumulations of wood shavings, insulation, and other gnawed material indicate active infestations. Size of entry holes (often 1 1/2 inches [4 cm] in diameter or less for mice, 2 inches [5 cm] or larger for rats) or tooth marks can be used to distinguish rat from mouse gnawing. Rats keep their paired incisor teeth, which grow continuously at the rate of about 5 inches (13 cm) per year, worn down by gnawing on hard surfaces and by working them against each other.

Sounds such as gnawing, climbing in walls, clawing, various squeaks, and fighting noises are common where rats are present, particularly at times of the day when they are most active.

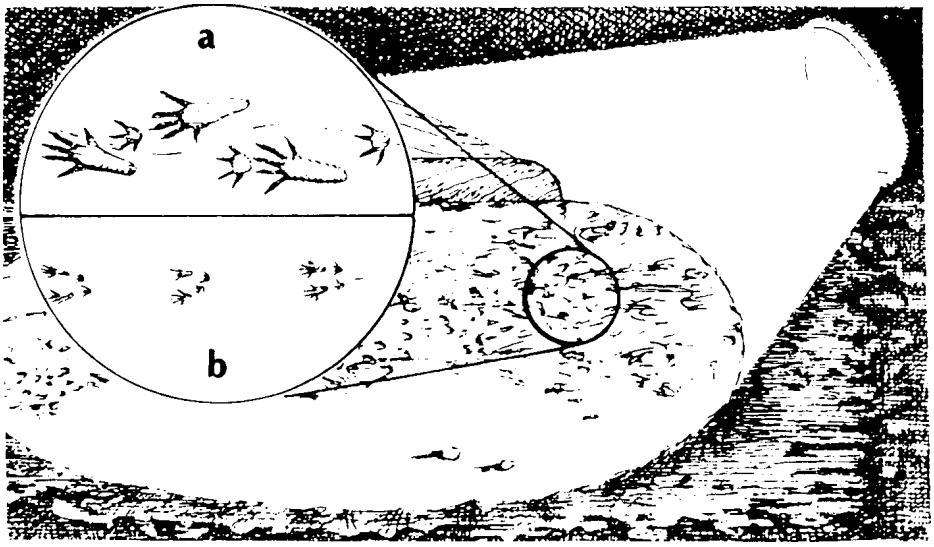


Fig. 4. Tracks left in dust by (a) Norway rat and (b) house mouse.

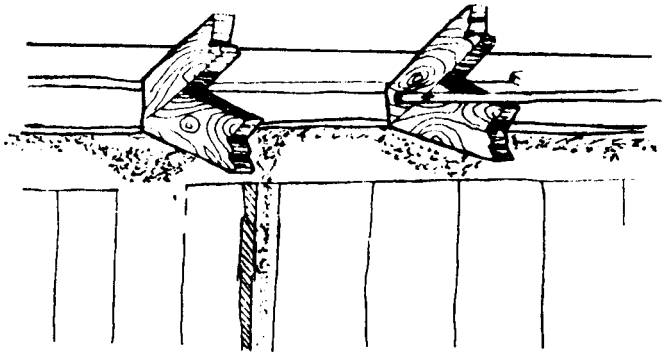


Fig. 5. Rub marks along beams, rafters, or other travel routes are evidence of rat activity.

Estimating Rat Numbers

Rat sign and visual sightings are of limited value in accurately estimating rat numbers, but they are the simplest and often the only practical method available. Search premises thoroughly when looking for rats. In structures, searches should include attics, basements, around foundations, crawl spaces, and behind and under stored materials. The following estimates can then be made:

No sign: no rats or few present. If only a few rats are present they may have invaded only recently.

Old droppings and gnawing common, one or more rats seen by flashlight at night, or no rats observed in daytime: medium numbers present.

Fresh droppings, tracks, and gnawing present, three or more rats seen at night, or rats seen in daytime: large numbers present.

Since rats are normally nocturnal and somewhat wary of humans, usually many more rats are present than will be seen in the daytime. Under certain conditions, rats may become quite bold in the presence of humans, and then a high percentage of the population may be visible.

A conservative estimate of rat numbers can be made from measuring their food consumption. You can do this by feeding the rats for a while on finely ground grain (whole grains or pelleted foods may be carried off uneaten). When offered over a period of time, the ground grain will usually be accepted and eaten by rats. Consumption may gradually increase to a maximum level over the period of a

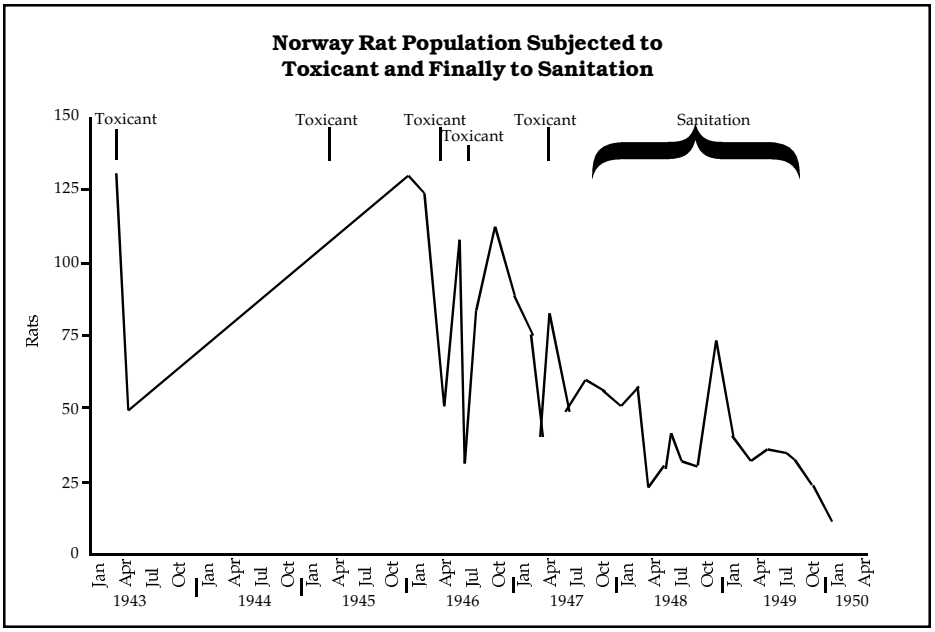


Fig. 6. Where repeated use of toxicants did not give lasting control, the use of sanitation (reduction of rats' food and shelter) assisted in reducing rat numbers.

week or so as the rats' natural fear of novel foods is overcome. Divide the total amount of food eaten per day by 1/2 ounce (15 g); this will give a minimum estimate of the rats present. Some rats eat more than 1/2 ounce (15 g) daily, but rats will probably also be using other foods in their environment. If too much alternative food is available, this technique will not give an adequate estimate.

Legal Status

Norway rats are not protected by law. They may be controlled with any pesticide registered by federal or state authorities for this purpose, or they may be controlled by use of mechanical methods such as traps.

Damage Prevention and Control Methods

Exclusion

Physical barriers can prevent rats from gaining entry to structures where food and shelter are available. "Rat-proofing" is an important and often neglected aspect of rat control. It is a relatively permanent form of rodent control that prevents damage from occurring.

To exclude rats, seal all holes and openings larger than 1/2 inch (1.3 cm) across. Rodent-proofing should be done with heavy materials that will resist rodent gnawing. These include concrete mortar, galvanized sheet metal, and heavy-gauge hardware cloth.

For more detailed information on rodent-proofing techniques, see the chapter **Rodent-Proof Construction and Exclusion Methods.**

Habitat Modification

In addition to the above-mentioned techniques of excluding rodents from sources of food and shelter, sanitation can play an important role in controlling rat populations (Fig. 6). Poor sanitation is one of the basic reasons for the continued existence of moderate to high rat populations in urban and suburban areas. In agricultural environments, proper sanitation cannot always eliminate rat populations, but it can often prevent rats from flourishing in large numbers.

Sanitation involves good housekeeping, including proper storage and handling of food materials, feed, and edible garbage. Warehouses, granaries and grain mills, silos, port facilities, and similar structures may provide excellent habitat for rats. Store bulk foods in rodent-proof containers or rooms. Stack sacked or boxed foods in orderly rows on pallets in a way that allows thorough inspection for evidence of rats. In such storage areas, keep stored materials away from walls. A 12-inch (30-cm) white band painted on the floor adjacent to the wall will aid in detecting rodent droppings and other rat sign (Fig. 7). Sweep floors frequently to permit ready detection of fresh sign.

Pet foods often are a source of food for rats in and around homes. Keep all such materials stored in metal rodent-proof containers. Feed pets only what they will eat at a single time.

Garbage and rubbish from homes, restaurants, farms, and other such sources should be properly stored and subsequently removed for disposal. A proper refuse storage container is heavy-duty, rust-resistant, rat- and damage-resistant, and equipped with a tight-fitting lid. Galvanized steel trash containers in good condition are better than those made of vinyl or plastic. Racks or stands prevent corrosion or rusting of containers, reduce rat shelter under containers, and minimize the chance of containers being overturned (Fig. 8).

Bulk storage containers for refuse, such as those used at apartments, businesses, and housing projects, should be similarly rodent-proof. Large metal refuse containers (dumpsters) sometimes have drain holes to facilitate cleaning. These drain holes should be fitted with a wire mesh screen or a removable plug; otherwise, the container becomes a huge feeding station for rodents (Fig. 9).

Refuse should be collected regularly and before refuse storage containers become filled to excess. Sanitary landfills and incinerators seldom have conditions that will allow rat populations to exist. On the other hand, open refuse dumps are often infested by Norway rats. At a properly operated sanitary landfill, garbage and rubbish are compacted and covered with earth daily. Modern incinerators completely burn refuse, and the resulting residue does not provide food for rats.

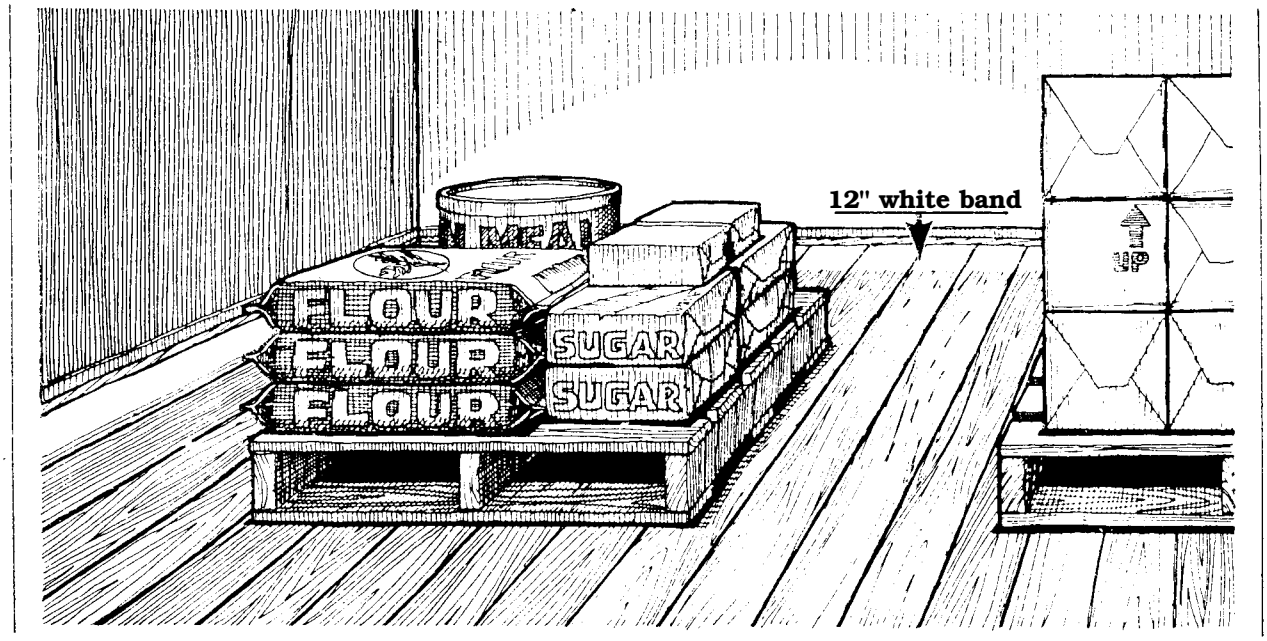


Fig. 7. A 12-inch (30-cm) white painted band makes inspection for rodent sign easier and reminds personnel to practice good sanitation.

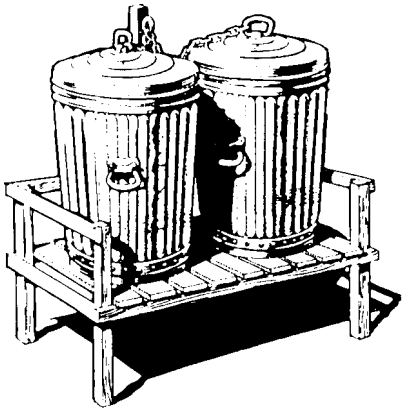


Fig. 8. Sturdy refuse containers on racks eliminate a source of food and shelter for rats.

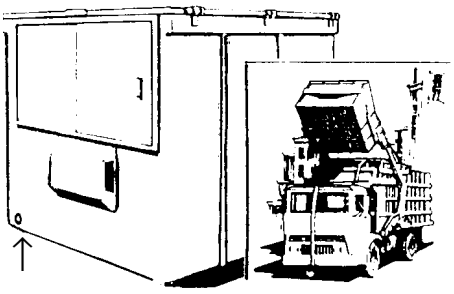


Fig. 9. Large metal refuse bins often have drainage holes (arrow). These should be plugged or screened to prevent rodent entry.

Sewers are inhabited by Norway rats in some towns and cities. Rats may enter at outlets and through manholes, catch basins, broken pipes, or drains. Since Norway rats are excellent swimmers, water traps do not impede their movement; in fact, they can travel upstream against a current. The problem of rats in sewers is usually greatest in places where sanitary sewers are interconnected with storm sewers, thus providing multiple entry points for rats. The domestic sewage of an average community provides enough food to sustain a large number of rats; this problem has increased as a result of the recent prevalence of garbage disposal units in most newer homes.

Regular removal of debris and control of weeds from around structures will reduce the amount of shelter available to rats. In some instances, a strip of heavy gravel placed adjacent to building foundations or other structures will reduce rat burrowing at these locations. Gravel should be at least 1 inch (2.5 cm) in diameter and laid in a band at least 2 feet (0.6 m) wide and 1/2 foot (15 cm) deep. In any event, keep the perimeter of buildings and other structures clean of weeds and debris (including stacked lumber, firewood, and other stored materials) to discourage rat activity and to allow easier detection of rat sign.

Frightening

Rats are wary animals and can be frightened easily by unfamiliar sounds or sounds coming from new locations. Most rodents, however, can quickly become accustomed to new sounds heard repeatedly. For years, devices that produce ultrasonic sound that is claimed to control rodents have come and gone on the market. There is little evidence to suggest that rodents' responses to nonspecific, high-frequency sound is any different from their response to sound within the range human of hearing.

What is known about rodents and sound?

— Unusually loud, novel sounds, including ultrasonic sounds, which rats can hear, will frighten them and may cause temporary avoidance lasting from a few minutes to weeks or months.

What is known about ultrasonic sound?

— It is very directional and does not travel around corners well; thus, sound shadows or voids are created.

— Ultrasound does not travel very far. It loses its intensity rapidly as it leaves the source.

— Ultrasound has not been shown to drive established rodents out of buildings or areas, nor has it been proven to cause above-normal mortality in their populations. While it is possible to cause convulsions or permanent physiological damage to rodents with ultrasound, the intensity of such sounds must be so great that damage to humans or domestic animals would also be likely. Commercial ultrasonic pest control devices do not produce sound of such intensity.

Tests of commercial ultrasonic devices have indicated that rats may be repelled from the immediate area of the ultrasound for a few days, but then will return and resume normal activities. Other tests have shown the degree of repellency to depend upon the particular ultrasonic frequencies used, their intensity, and the preexisting condition of the rodent infestation. Ultrasonic sound has very limited usefulness in rodent control. The advertising claims for many commercial devices are unsubstantiated by scientific research. Since commercial ultrasonic devices are often expensive and of questionable effectiveness, they cannot be recommended as a solution to rodent problems.

Repellents

Rats find some types of tastes and odors objectionable, but chemical repellents are seldom a practical solution to rat infestations. Substances such as moth balls (naphthalene) or household ammonia, in sufficient concentration, may have at least temporary effects in keeping rats out of certain enclosed areas. The above materials, however, are not registered by the EPA as rat repellents.

Ro-pel® is registered for use in repelling Norway rats and other rodents from gnawing on trees, poles, fences, shrubs, garbage, and other objects. Little information is currently available on its effectiveness against rats.

Other solutions to rat problems, including rodent-proof construction and methods of population reduction, are usually more permanent and cost-effective.

Toxicants

Rodenticides were formerly classified into two groups, single-dose (acute) toxicants and multiple-dose (chronic) rodenticides. However, the complexity in mode of action of newer rodenticides makes these classifications outdated. A classification into two groups, the first including all anticoagulants, and the second all other compounds ("non-anticoagulants"), is currently more useful.

Anticoagulants (slow-acting, chronic toxicants). The anticoagulant rodenticides have been the most preferred materials for controlling rats since their initial development following World War II. They are quite acceptable to rats, do not cause bait shyness, are easy to apply, and if used properly, are relatively safe to use around livestock, pets, and humans.

Rats poisoned with anticoagulants die from internal bleeding, the result of loss of the blood's clotting ability and damage to the capillaries. Animals killed by anticoagulants may show extreme lack of color of the skin, muscles, and viscera. Hemorrhage may be found in any part of the body. Prior to death, the animal exhibits increasing weakness due to blood loss.

Several anticoagulant compounds are registered for controlling Norway rats (Table 1). With the exception of two (bromadiolone and brodifacoum), multiple feedings over a period of several days are usually required to cause death. Relatively low, chronic doses are fatal, whereas the same amount of toxicant ingested at a single feeding may produce no significant effect to the rodent. However, this may vary for different anticoagulants. Feeding

Table 1. Anticoagulants used for Norway rat control in the United States.

Common name and typical trade names	Chemical name	Usual types of formulations			Percent active ingredient used in food bait
		Food Bait	Liquid	Tracking Powder	
Hydroxycoumarins					
Warfarin (Final® and others)	3-(α-acetonylbenzyl)-4-hydroxycoumarin	X	X		0.025
Brodifacoum (Talon®)*	3-[3(4'-bromo[1,1′biphenyl]-4-yl)-1,2,3,4-tetrahydro-1-naphthalenyl]-4-hydroxy-2H-1-benzopyran-2-one	X			0.005
Bromadiolone (Maki®, Contrac®)*	3-[3-(4'-bromo[1,1′biphenyl]-4-yl)-3-hydroxy-1-phenylpropyl]-4-hydroxy-2H-1-benzopyran-2-one	X			0.005
Difethialone*	[(bromo-4'-0[biphenyl-1-1'] yl-4) 3-tetrahydro-1,2,3,4-napthyl-1] 3-hydroxy-4, 2H-1-benzo-thiopyran-2-one	X			0.0025
Indandiones					
Chlorophacinone (RoZol®)	2-[(p-chlorophenyl)phenylacetyl]-1,3-indandione	X		X	0.005
Diphacinone (Ramik®, Ditrac®)	2-diphenylacetyl-1,3-indandione	X		X	0.005
Pindone (Pival®, Pivalyn®)	2-pivalyl-1,3-indandione	X	X		0.025

*Second-generation anticoagulants especially useful for the control of warfarin-resistant rats and mice.

does not always have to be on consecutive days. When anticoagulants are eaten daily, however, death may occur as early as the third or fourth day. For optimal lethal effects, several feedings should occur within a 10-day period with no longer than 48 hours between feedings.

All anticoagulants provide good to excellent Norway rat control when prepared in acceptable baits. A new second-generation anticoagulant, difethialone, is presently being developed and EPA registration is anticipated in the near future. The characteristics of the various anticoagulant rodenticides are described further in the **Pesticides** section.

Because of their similarity in mode of action, all anticoagulant baits are used in a similar fashion. Label directions commonly instruct the user to "maintain a continuous supply of bait for 15 days or until feeding ceases," thus ensuring that the entire rat population has ample opportunity to ingest a lethal dose of the bait. Anticoagulants have the same effect on nearly all warm-blooded animals, but the sensitivity to these toxicants varies among species. If misused, anticoagulant rodenticides can be lethal to nontarget animals such as dogs, pigs, and cats. Additionally, residues of anticoagulants which are present in the bodies of dead or dying rodents can cause toxic effects to scavengers and predators. In general, however, the secondary poisoning hazard from anticoagulants is relatively low.

Brodifacoum and bromadiolone baits, because of their potential to be lethal in a single feeding, can be more effective than the other anticoagulants in certain situations.

Chlorophacinone (RoZol®) and diphacinone (Ramik®, Ditrac®) are similar in potency and are more toxic than the anticoagulant compounds developed earlier. Thus, they are formulated at lower concentrations. Chlorophacinone and diphacinone may kill some rats in a single feeding, but multiple feedings are needed to give adequate control of an entire rat population.

Pindone (Pival®, Pivalyn®) is also less potent than chlorophacinone or diphacinone, and it is regarded as slightly less effective than warfarin against Norway rats. It has some properties that resist insects and growth of mold in prepared baits.

Warfarin (Final® and other trade names) was the first marketed anticoagulant and therefore became the best known and most widely used. It is effective against Norway rats, although some products may contain small quantities of contaminants that apparently can reduce bait acceptance. This problem was resolved by the development of micro-encapsulated warfarin.

Anticoagulant Resistance. Within any population of Norway rats, some individuals are less sensitive to anticoagulants than others. Where anticoagulants have been used over long periods of time at a particular location, there is an increased potential for the existence of a population that is somewhat resistant to the lethal effects of the baits. Such resistant populations of rats have been identified at a number of locations throughout the United States. Although not common, resistance may be underestimated because documentation of resistance is usually not pursued by persons involved in operational rat control programs.

Resistance, if and when it occurs, is of little consequence in the control of Norway rats, especially with the newer rodenticides presently available. When anticoagulant resistance to the first-generation anticoagulants is known or suspected, use of these compounds should be avoided in favor of the second-generation anticoagulants or one of the non-anticoagulant products.

Anticoagulant Bait Failure. Resistance is only one (and perhaps the least likely) reason for failure in the control of rats with anticoagulant baits. Control with baits that are highly accepted may fail for one or more of the following reasons:

— Too short a period of bait exposure.

— Insufficient bait and insufficient replenishment of bait (none remains from one baiting to the next).

— Too few bait stations and/or too far apart. In some situations, stations may have to be within 20 to 30 feet (7 to 10 m) of one another.

— Too small a control area, permitting rats to move in from untreated adjacent areas.

— Genetic resistance to the anticoagulant. Although this is unlikely, it should be suspected if about the same amount of bait is taken daily for a number of weeks.

Control with anticoagulant baits that are poorly accepted may fail for one or more of the following reasons:

— Poor bait choice, or bait is formulated improperly. Other foods are more attractive to the rats.

— Improperly placed bait stations. Other foods are more convenient to the rats.

— Abundance of other food choices.

— Tainted bait: the bait has become moldy, rancid, insect-infested, or contaminated with other material that reduces acceptance. Discard old bait periodically, and replace it with fresh bait.

Occasionally, rats accept bait well and an initial population reduction is successful. Then bait acceptance appears to stop although some rats remain. In such instances it is likely that the remaining rats never accepted the bait either because of its formulation or placement. The best strategy is then to switch to a different bait formulation, place baits at different locations, and/or use other control methods such as traps.

Other Rodenticides. The older rodenticides, formerly referred to as acute toxicants, such as ANTU, arsenic trioxide, phosphorus, and Compound 1080, are no longer registered for rat control. The widespread availability of ready-to-use anticoagulants and their relative effectiveness have resulted in the reduced use of these older materials over the last 20 years.

Table 2. Other (non-anticoagulant) rodenticides used to control Norway rats in the United States.

Common Name	Chemical Name	Acute oral LD_{50} for rats mg/kg	Time to death	Odor	Taste	Percent active ingredient in food bait	Relative Hazard	Mode of Action
Bromethalin (Assault®, Vengeance®)	N-methyl-2,4-dinitro-N-(2,4,6-tribromophenyl)-6-(trifluoromethyl) benzenamine	2-5	2-4 days	None	Slight	0.01	Moderate	Central nervous system depression and paralysis
Cholecalciferol (Quintox®, vitamin D_3)	9,10-Seocholesta-5,7,10 (19)-trein-3 betaol	10-50	3-4 days	Slight	None	0.075	Low to moderate	Mobilizes calcium resulting in death from hypercalcemia
Red squill	scilliroside glycoside*	200-490	< 24 hrs.	Medium	Strong	10	Low	Heart
Zinc phosphide	zinc phosphide	27-40	1/2-20 hours	Strong	Strong	1.0-2.0	Moderate	Phosphine gas enters circulatory system; heart paralysis, gastro-intestinal and liver damage

* principal active ingredient

At present, four non-anticoagulant rodenticides (Table 2) are registered by EPA against Norway rats: bromethalin, cholecalciferol (vitamin D_3), red squill, and zinc phosphide. All are potentially useful for controlling anticoagulant-resistant populations of rats.

Of these active ingredients, bromethalin and cholecalciferol are formulated to serve as chronic rodenticides, applied so that rats will have the opportunity to feed on the baits one or more times over the period of one to several days. Bait acceptance is generally good when formulations appropriate for rats are selected. Zinc phosphide and red squill differ in that prebaiting (offering rats similar but nontoxic bait prior to applying the toxicant-treated bait) is recommended to increase bait acceptance. These two rodenticides are not designed to be left available to rats for more than a few days, as continued exposure is likely to result in bait shyness within the population. Be sure to follow label recommendations on any specific product to achieve best success.

Non-anticoagulant rodenticides, particularly zinc phosphide, remain useful tools to achieve quick reductions in rat populations. When rat numbers are large, the cost of baiting with these materials may be lower than for the anticoagulants.

Bromethalin (Assault®, Vengeance®) is formulated in a ready-to-use bait as a chronic rodenticide, applied so that rats will have the opportunity to feed on the bait one or more times over a period of one to several days. Because it is a slow-acting in comparison to zinc phosphide or red squill, bait shyness is not usually a problem, nor is prebaiting necessary to get good control in most situations.

Cholecalciferol (vitamin D_3, Quintox®) is similarly formulated in a ready-to-use bait, serving as a chronic rodenticide. Death occurs 3 or 4 days after ingestion of a lethal dose. Because the toxicant is slow-acting, bait shyness is not reported to occur. It is claimed that rodents cease feeding once a lethal dose has been ingested.

Red squill is a relatively selective and safe toxicant for use only against Norway rats. It acts as an emetic, which provides some degree of protection to certain nontarget species that might accidentally consume the bait. Rats, which cannot vomit, are unable to rid themselves of the toxicant once it is consumed. In the past, one problem was the variation in the quality of the material, which is derived from a plant. Red squill must be stored in a sealed container, as moisture will cause loss of potency.

Zinc phosphide is a dark gray powder, insoluble in water, that has been used extensively in the control of rodents. It is available in ready-to-use dry baits and also in concentrates for use by persons trained in rodent control who may wish to prepare their own baits. Its strong garlic-like odor appears to be attractive to rodents that are not bait-shy. Oils and fats make excellent binders for zinc phosphide and increase absorption of the toxicant when ingested. An effective bait is made from mixing zinc phosphide with meat such as canned fish-flavored cat food. Rats will readily accept this bait, especially if adequate prebaiting has been done beforehand.

The following general steps are recommended to obtain good bait acceptance, and therefore good rat control, when using zinc phosphide baits:

1. Prebait rats for a minimum of 3 to 5 days to get the rats accustomed to eating the nontoxic bait material. Do not change types of bait during the prebaiting or baiting operation. Apply prebait at many locations, wherever there is rat activity. Where bait is completely eaten overnight, double the amount of prebait at that location the next day. Repeat this procedure until the amount of bait eaten every night no longer increases.

2. Use only high-quality grains and fresh ready-to-use baits. Where rats have access to abundant amounts of grain, meat such as canned fish-flavored cat food may be a good substitute. Obtain a sufficient quantity to complete the project without changing brands or flavors.
3. Wait until prebait consumption has peaked before applying toxic baits. Remove any uneaten prebait and place the toxic bait at the same locations that the prebait was applied. Usually, the amount of toxic bait needed will be about half the amount used on the last day that prebait was applied. It may be helpful to wait one day between the last application of prebait and application of toxic bait. That way, rats will be hungrier. Mix the toxicant into the bait ingredients according to label directions, if preparing your own baits from a concentrate.
4. Avoid handling the toxic bait or rodenticide concentrate with bare hands; use rubber or latex gloves. Clean thoroughly any tools or containers used in bait mixing, or safely dispose of them as well as bait packaging materials.
5. Confine or restrain any pets, livestock, or other animals that may otherwise gain access to and feed on the bait. It may also be necessary to place prebait and toxic bait into bait boxes for safety.
6. Following toxic bait application, pick up and dispose of available dead rats and all uneaten bait by incineration or deep burial. Normally, bait should be exposed for only 1 or 2 nights; the greatest consumption occurs on the first night.
7. Control remaining rats by using anticoagulant baits or by using traps or burrow fumigants.

Bait Selection and Formulation

Contrary to popular belief, rats prefer fresh, high-quality foods and will reject spoiled or inferior foods item when given a choice. Therefore, rodent baits should be made from high-quality food materials.

Usually corn, oats, wheat, or barley are the grains most preferred by Norway rats. Preference will vary between rat populations and among individual rats. Baits similar to foods rats are accustomed to eating are often a good choice, particularly if their normal foods are limited or can be made less available to them. Some people trained in rodent control prefer to mix their own baits. Ground cereal grains are often mixed with 5% powdered sugar and 3% to 10% vegetable oil. A toxicant concentrate is added to this mixture in the proper amount. Certain anticoagulants, as well as zinc phosphide, can be purchased in concentrate forms for use in formulating baits. Under some conditions, baits made with fruits, vegetables, meat, or fish may be highly accepted. Use of such bait materials, however, may increase the risk of poisoning cats, dogs, domestic animals, and other nontarget species.

To determine bait preference in rats, conduct a bait-choice test by placing about 4 ounces (115 g) of each of several nontoxic baits about one foot (30 cm) apart in several locations where rats are present. Check baits for the next few days to find out which foods rats preferred. Keep in mind that rats are suspicious of new objects and novel foods; therefore, they may not accept a new bait until the third or fourth day.

The ready-to-use baits most available to the public are anticoagulant rodenticides. Several types are available. Grain-based baits in a loose meal or pelleted form are available in bulk or packaged in small, 4- to 16-ounce (112- to 454-g) plastic, cellophane, or paper "place packs" (Fig. 10). These packets keep bait fresh and make it easy to place baits into burrows, walls, or other locations. Rats will gnaw into these bags to feed on acceptable baits. Pelleted baits can more easily be carried by rats to other locations. Such hoarding of food by rats is not uncommon. It may result in amounts of bait being moved to places where it is undetected or difficult to recover and may, if accessible, be hazardous to nontarget species.

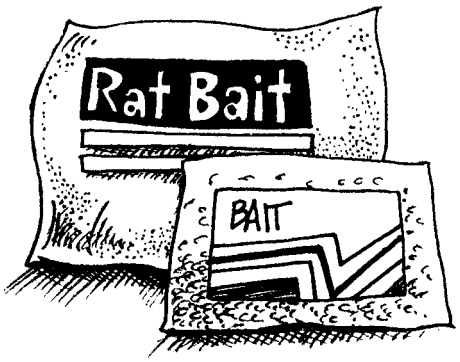


Fig. 10. Various types of place packs containing ready-to-use rodenticides are commercially available.

Anticoagulant baits have also been formulated into wax and extruded blocks (Fig. 11). These are particularly useful in sewers or where moisture may cause loose grain baits to spoil. Rats accept paraffin block baits less readily than loose or pelleted grain baits, but acceptance of extruded bait blocks is high.

Sodium salts of anticoagulants are available as concentrates to be mixed with water, making a liquid bait (Fig. 12). Since rats require water daily, they can be drawn to water stations where other water sources are scarce. Water baits are particularly useful in grain storage structures, warehouses, and other such locations. Rodents are more easily able to detect anticoagulants in water baits than in food baits; therefore, up to 5% sugar is sometimes added to liquid baits to increase rats' acceptance of the bait solution. Since water is attractive to most animals, use water baits in ways that prevent nontarget animals from drinking them.

Bait Stations

Bait stations (bait boxes) may increase both the effectiveness and safety of rodenticides. They came into general use after the development of the first-generation anticoagulants, which require that a continuous supply of bait be made available to rodents. Bait stations are useful because they:

— protect bait from moisture and dust;

— provide a protected place for rodents to feed, allowing them to feel more secure;

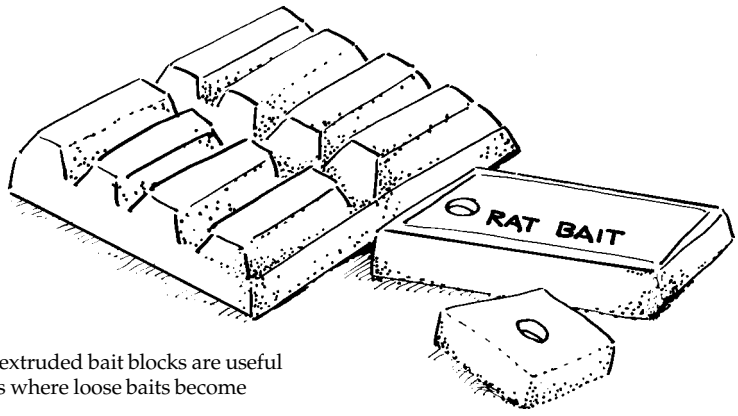
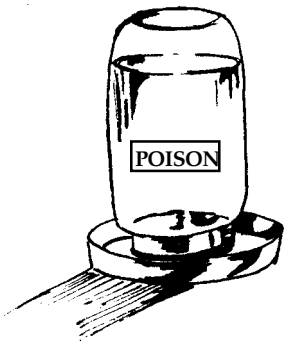


Fig. 11. Wax and extruded bait blocks are useful in damp locations where loose baits become spoiled quickly.



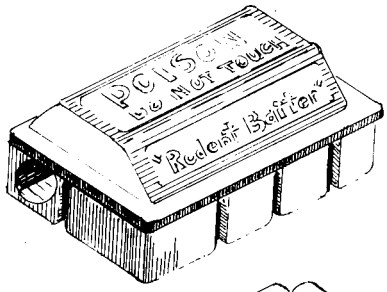


Fig. 12. Liquid baits can be placed in fonts or other similar containers.

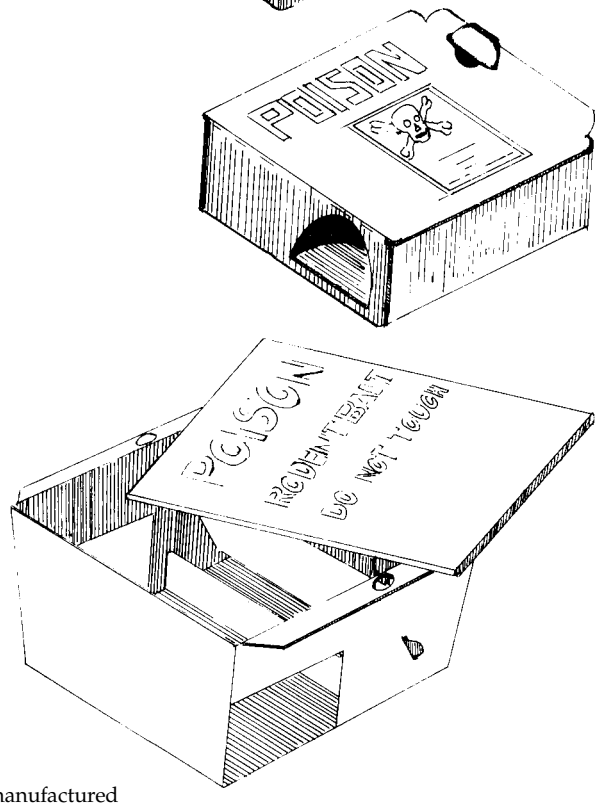


Fig. 13. Examples of commercially manufactured rodent bait stations.

— keep other animals (pets, livestock, desirable wildlife) and children away from hazardous bait;

— allow placement of bait in locations where it would otherwise be difficult because of weather or potential hazards to nontarget animals;

— help prevent the accidental spilling of bait;

— allow easy inspection of bait to see if rodents are feeding on it.

Kinds of Bait Stations. Bait stations can contain solid baits liquid baits, or both. Bait boxes can be purchased from commercial suppliers or made at home. Manufactured bait boxes made of plastic, cardboard, or metal (Fig. 13) are sold to pest control companies and to the public in sizes for rats or mice. Some farm supply and agricultural chemical supply stores have them in stock or can order them.

Bait boxes can be built from scrap materials, and homemade stations can be deigned to fit individual needs. Make them out of sturdy materials so they cannot be easily knocked out of place or damaged. Where children, pets, or livestock are present, be careful to construct the stations so that the bait is accessible only to rodents. Locks, seals, or concealed latches are often used to make bait boxes more tamperproof. In some situations, stations should be secured in place. Clearly label all bait boxes or stations with "Poison" or "Rodent Bait — Do Not Touch," or with a similar warning. Some rodenticides or situations may require use of tamper-resistant bait stations. If so, use only bait boxes or stations which are so designated, and also be sure to secure them to buildings by nailing or gluing them to walls or floors in a way that will not permit a person or animal to knock them over or shake the bait out.

Bait Station Design. Bait stations should be large enough to allow several rodents to feed at once. They can be as simple as a flat board nailed at an angle to the bottom of a wall (Fig. 14), or a length of pipe into which bait can be placed (Fig. 15). More elaborate stations are completely enclosed and can

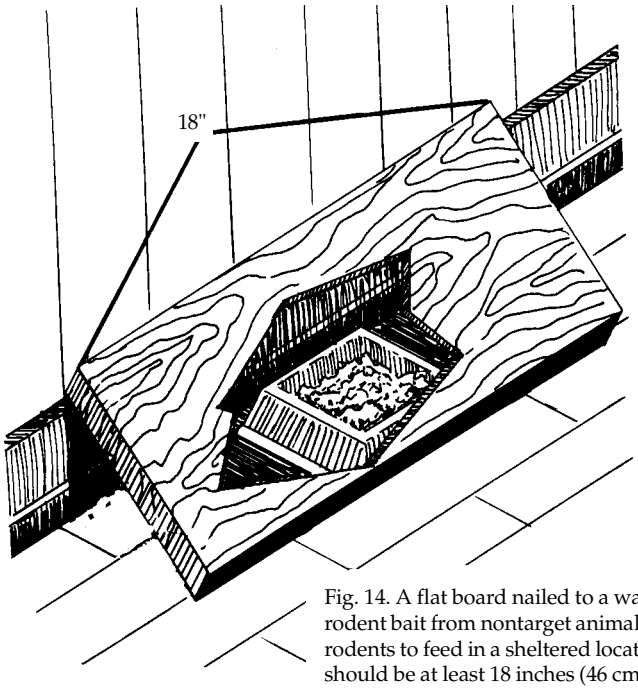


Fig. 14. A flat board nailed to a wall protects rodent bait from nontarget animals and allows rodents to feed in a sheltered location. The board should be at least 18 inches (46 cm) long to keep pets and children from reaching the bait.

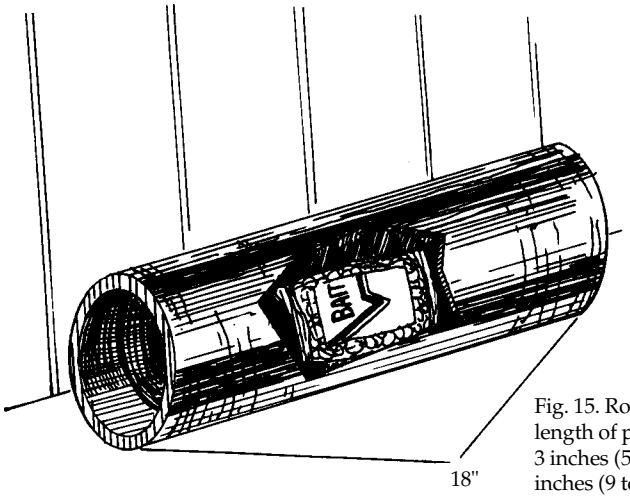


Fig. 15. Rodent bait station made from a length of pipe. Pipe diameter can be 2 to 3 inches (5 to 8 cm) for mice; 3 1/2 to 6 inches (9 to 15 cm) for rats.

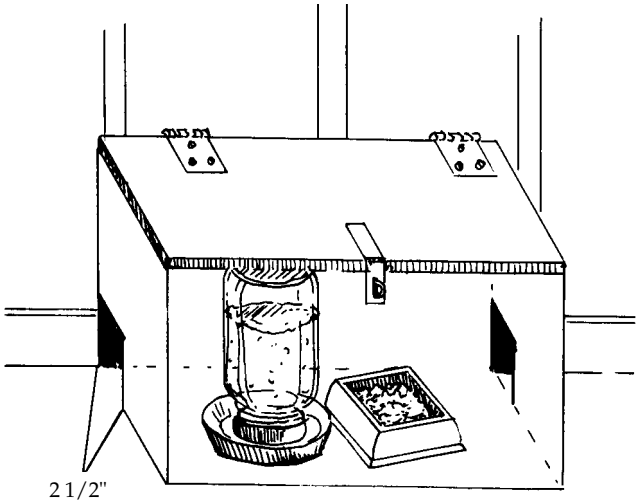


Fig. 16. A homemade rodent bait station can contain liquid as well as solid baits.

contain liquid as well as solid baits (Fig. 16). A hinged lid with a child-proof latch can be used for convenience in inspecting permanent stations.

Bait stations for rats should have at least two openings approximately 2 1/2 inches (6 cm) in diameter. The two holes should be on opposite sides of the station because rodents can see an alternate escape route as they enter the station.

Bait Station Maintenance. Baits must be fresh and of high quality. Rats will reject spoiled or stale foods. Provide enough fresh bait to allow rodents to eat all they want. When you first put bait boxes out, check them daily and add fresh bait as needed. After a short time, rodent numbers and feeding will decline, and you will need to check the boxes only every 2 weeks or once a month. If the bait becomes moldy, musty, soiled, or insect-infested, empty the box and clean it, and then refill it with fresh bait. Dispose of spoiled or uneaten bait in accordance with the label. Follow all label directions for the product you are using.

Placement of Bait Stations. Proper placement of bait stations is just as important as bait selection. Rats will not visit bait stations, regardless of their contents, if they are not conveniently located in areas where rodents are active.

Where possible, place bait between the rodents' source of shelter and their food supply. Put bait boxes near rodent burrows, against walls, or along travel routes. Since rats are often suspicious of new or unfamiliar objects, it may take several days for them to enter and feed in bait stations.

On farmsteads, bait station placement depends on building design and use. In swine confinement buildings, it may be possible to attach bait boxes to wall ledges or the top of pen dividing walls. Bait boxes may be placed in attics or along the floors or alleys where rodents are active (Fig. 17). Rodent tracks visible on dusty surfaces and their droppings often give clues to where they are active.

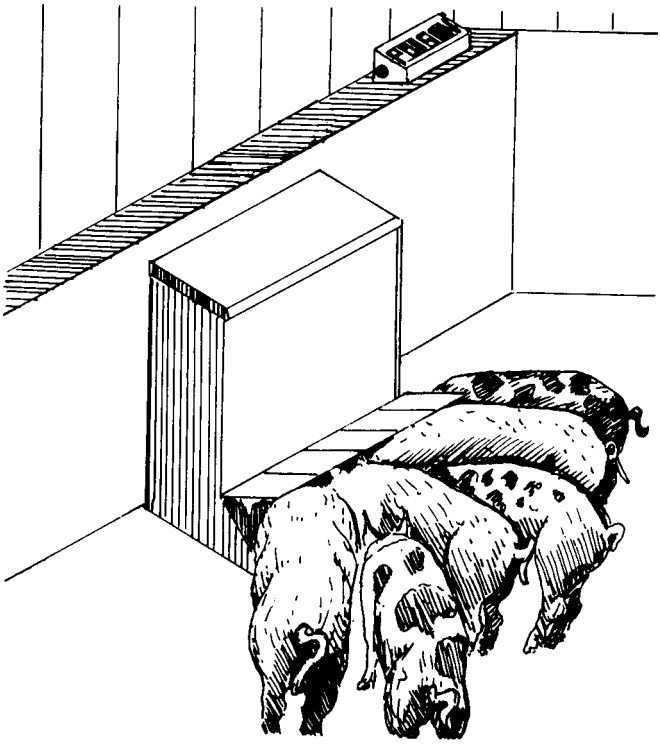


Fig. 17. Rodent bait box attached to the top of a pen dividing wall in a swine confinement facility. When used in such locations, bait boxes must be securely fastened and out of pigs' reach.

Never place bait stations where livestock, pets, or other animals can knock them over. Spilled bait may be a potential hazard, particularly to smaller animals.

Where buildings are not rodent-proof, permanent bait stations can be placed inside buildings, along the outside of building foundations, or around the perimeter. Bait stations will help keep rodent numbers at a low level when maintained regularly with fresh anticoagulant bait. Rodents moving in from nearby areas will be controlled before they can reproduce and cause serious damage.

Tracking Powders. Toxic dusts or powders have been successfully used for many years to control rats and mice. When rodents walk through a patch of toxic powder, they pick some of it up on their feet and fur and later ingest it while grooming. Tracking powders are useful in controlling rats where food is plentiful and good bait acceptance is difficult to achieve. Rats are more likely to ingest a lethal amount of a poorly accepted toxicant applied by this method than if it is mixed into a bait material. There is little likelihood of toxicant shyness developing when using tracking powders.

Because the amount of material a rat may ingest while grooming is small, the concentration of active ingredient in tracking powders is considerably higher than in food baits that utilize the same toxicant. Therefore, these materials can be more hazardous than food baits. For the most part, tracking powders are used by professional pest control operators and others trained in rodent control. Currently, the only tracking powders registered for use against Norway rats contain anticoagulants.

Place tracking powders in rat burrows, along runways, in walls, behind boards along walls, or on the floor of bait stations. Placement can be aided by using various types of sifters, shakers, or blowers. Dampness may cause the powder to cake and lessen its effectiveness. Care must be taken to place tracking powders only where they cannot contaminate food or animal feed, or where nontarget animals cannot come into contact with them. Do not place tracking powders where rats can track the material onto food intended for use by humans or domestic animals. Tracking powders are not generally recommended for use in and around homes because of potential hazards to children and pets. Where possible, remove tracking powder after the rodent control program is completed.

Fumigants

Fumigants (toxic gases) are most commonly used to control rats in their burrows at outdoor locations. Compounds including aluminum phosphide, chloropicrin, and gas cartridges, are registered for this purpose. The incendiary gas cartridge burns, producing carbon monoxide and other gases that suffocate rodents in their burrows. Methyl bromide is presently registered only for fumigation of structures by qualified professionals. Anhydrous ammonia is not recommended for use as a burrow fumigant because it is not registered for this purpose. For further information on fumigants, see the **Pesticides** section.

Fumigants should only be used by people familiar with the necessary precautions because they are highly toxic to humans and other animals. Do not use fumigants in any situation that might expose the occupants of a building to the fumes. Only licensed structural pest control operators should use fumigants in buildings or other structures.

To fumigate rat burrows, close the burrow opening with soil or sod immediately after introduction of the fumigant. Rat burrows often have multiple entrances, and all openings must be sealed in order for fumigants to be effective. Fumigants are less effective in soils that are very porous or dry.

Trapping

Trapping can be an effective method of controlling rats, but it requires more skill and labor than most other methods. Trapping is recommended where toxicants are inadvisable. It is the preferred method to try first in homes, garages, and other small structures where there may be only a few rats present.

Trapping has several advantages: (1) it does not rely on inherently hazardous rodenticides; (2) it permits the user to view his or her success; and (3) it allows for disposal of the rat carcasses, thereby eliminating odor problems from decomposing carcasses that may remain when poisoning is done within buildings.

The simple, inexpensive, wood-based snap trap is available in most hardware and farm supply stores. Traps should be baited with a small piece of hot dog, bacon, or nutmeat tied securely to the trigger. Peanut butter or marshmallows also may be used as bait. Baits that become stale lose their effectiveness.

Set traps close to walls, behind objects, in dark corners, and in places where rat activity is seen. Place the traps so that when rats follow their natural course of travel (usually close to a wall) they will pass directly over the trigger (Fig. 18). Set traps so that the trigger is sensitive and will spring easily. Effectiveness can be increased by enlarging the trigger. Attach a square of cardboard, metal, or screen wire that fits just inside the wire deadfall (Fig. 19).

Leaving traps unset until the bait has been taken at least once reduces the chance of rats escaping the trap and becoming trap-shy. Other kinds of traps are also effective in catching rats. Wire-mesh cage traps such as the National®, Tomahawk®, and Havahart® can be used effectively to capture rats alive (Fig. 20). Wire funnel-entrance traps have also been used to capture rats alive.

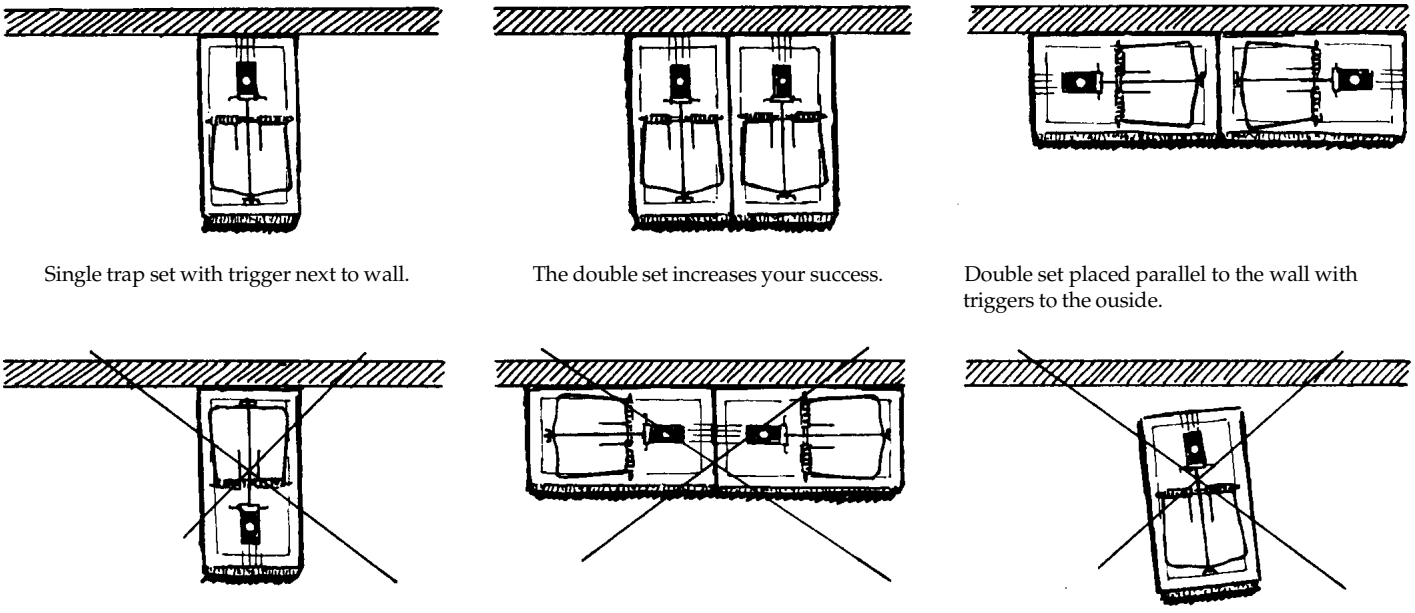
Keep traps reasonably clean and in good working condition. They can be cleaned with a hot detergent solution and a stiff brush. Human and dead-rat odors on traps are not known to reduce trapping success.

An alternative to traps are glue boards, which catch and hold rats attempting to cross them, much the same way flypaper catches flies. Place glue boards wherever rats travel — along walls or in established runways. Do not use glue boards where children, pets, or desirable wildlife can contact them. Glue boards lose their effectiveness in dusty areas unless covered, and temperature extremes may affect the tackiness of some glues. They are considered less effective for capturing rats than for mice. Glue boards can be purchased ready-to-use or they can be made. Euthanize live, trapped rodents by asphyxiation with carbon dioxide, or use a stick to kill them with sharp blows to the base of the skull. For further information on glue boards, see the **Supplies and Materials** section.

Other Methods

In some situations, rats can be killed manually with a club or other implement. When rats have access to a structure through only one or a few entrances, it may be possible to drive them out en masse. Then they can be clubbed or shot with a pellet gun or .22 firearm loaded with birdshot.

Some dogs and cats will catch and kill rats. There are few situations, however, in which they will do so sufficiently to control rat populations. Around most structures, rats can find many places to hide and rear their young out of the reach of such predators. Cats probably cannot eliminate existing rat populations, but in some situations they may be able to prevent reinfestations once rats have been controlled. Farm cats, if sufficient in number and supplementally fed, may serve this function.



Single trap set with trigger next to wall.

The double set increases your success.

Double set placed parallel to the wall with triggers to the ouside.

Wrong—trigger not next to wall.

Wrong—parallel set with triggers on the inside.

Wrong—trap too far from wall.

Fig. 18. Placement of snap traps

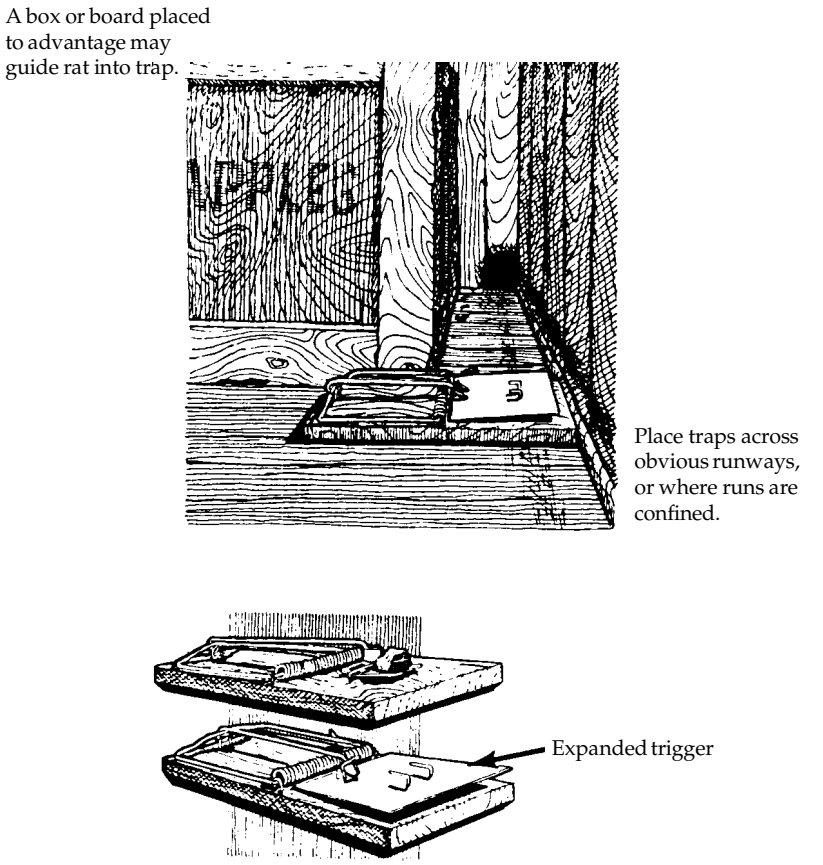


Fig. 19. Expanded-trigger traps, when properly placed, can be very effective.

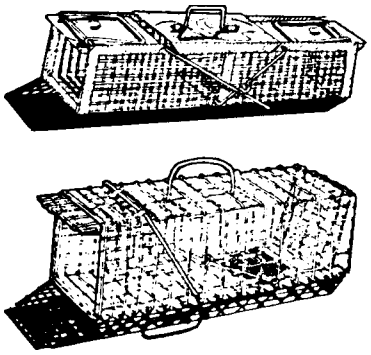


Fig. 20. Wire cage traps can be used to capture rats alive. Use enough traps to make the campaign short and decisive.

In urban and suburban areas, rats may be present because people have pets. It is not uncommon to find rats living in close association with cats and dogs, relying on cat and dog food for nourishment. Rats frequently live beneath dog houses and soon learn they can feed when the dog is absent or asleep.

Economics of Damage and Control

Accurate data on rat damage, control, and their cost is difficult to obtain. Estimates of losses of foodstuffs, structural damage, and the amount of labor and materials expended to control rats are usually only educated guesses. One study found that a small colony of Norway rats (10 to 26 animals), when given access to a ton of sacked wheat, would contaminate 70% of the grain after 12 to 28 weeks. The sacks were heavily damaged as well. Total damage equaled 18.2% of the total value of the wheat and the sacks.

One rat will eat approximately 20 to 40 pounds (9 to 18 kg) of feed per year and probably contaminates 10 times that amount with its urine and droppings. In a year's time, a single rat will produce some 25,000 droppings. A 1973 estimate states rats may cost the United States between $500 million and $1 billion annually in direct economic losses. In most cases, the cost of rat control—particularly when it is done in a timely fashion—is far less than the economic loss caused by rat damage.

Acknowledgments

I thank Rex E. Marsh for reviewing this chapter and providing many helpful comments. The material it contains includes information taken from Brooks 1973, Howard and Marsh 1981, and Pratt et al. 1977, among other sources.

Figures 1 and 3 from Schwartz and Schwartz (1981) adapted by Jill Sack Johnson.

Figures 2, 4, 6, 7, 8, 9, 19 and 20 adapted from Pratt et al. (1977) by Jill Sack Johnson.

Figures 5 and 18 adapted from Howard and Marsh (1981) by Jill Sack Johnson.

Figures 10, 11 and 12 by Jill Sack Johnson.

Figures 13, 16 and 17 by Frances I. Gould.

Figures 14 and 15 adapted from Pratt et al., (1977) by Frances I. Gould.

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Mark E. Tobin
Project Leader
Hawaii Field Station
Denver Wildlife Research Center
USDA-APHIS-ADC
Hilo, Hawaii 96721

POLYNESIAN RATS

Fig. 1. Polynesian rat, *Rattus exulans*

Damage Prevention and Control Methods

Exclusion

Not practical for Hawaiian sugarcane fields.

Cultural Methods

Synchronize planting and harvesting of large blocks of fields.

Eliminate or modify noncrop vegetation adjacent to sugarcane fields.

Develop potential resistant sugarcane varieties.

Repellents

None are registered.

Toxicants

Zinc phosphide.

Fumigants

Not practical in and around sugarcane fields.

Trapping

Not practical in and around sugarcane fields.

Shooting

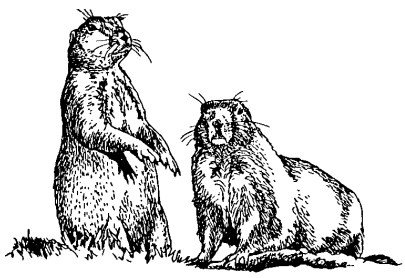
Not practical.

Biological Control

Not effective.

Identification

The Polynesian rat (*Rattus exulans*) is smaller than either the Norway rat (*R. norvegicus*) or the roof rat (*R. rattus*). Polynesian rats have slender bodies, pointed snouts, large ears, and relatively small, delicate feet. A ruddy brown back contrasts with a whitish belly. Mature individuals are 4.5 to 6 inches long (11.5 to 15.0 cm) from the tip of the nose to the base of the tail and weigh 1.5 to 3 ounces (40 to 80 g). The tail has prominent fine scaly rings and is about the same length as the head and body. Female Polynesian rats have 8 nipples, compared to 10 and 12 nipples normally found on roof rats and Norway rats, respectively.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

B-121

Range

Polynesian rats are native to Southeast Asia but have dispersed with humans across the central and western Pacific. Today, these rodents inhabit almost every Pacific island within 30° of the equator. They occur from the Asiatic mainland south to New Guinea and New Zealand, and east to the Hawaiian Islands and Easter Island. Polynesian rats accompanied early Polynesian immigrants to Hawaii and today occur on every major island of the archipelago. The Polynesian rat is not present in the mainland United States.

Habitat

In Hawaii, Polynesian rats are most common below 2,500 feet (750 m) elevation, although individuals have been captured at an elevation of 4,900 feet (1,500 m) on Mauna Loa on the island of Hawaii and 9,700 feet (2,950 m) on the rim of Haleakala Crater on Maui. Polynesian rats prefer areas with good ground cover on well-drained soil. Throughout much of their range, Polynesian rats live in close association with humans. In Hawaii, however, Polynesian rats are not a commensal pest, but rather favor wild lowland habitats such as wooded and grassy gulches, fields, and waste areas. They reach their highest densities on agricultural lands such as sugarcane fields and abandoned pineapple fields.

Food Habits

Polynesian rats eat a wide variety of foods, including broadleaf plants, grasses, fruits, seeds, and animal matter. They prefer fleshy fruits such as melastoma (*Melastoma malabathricum*), passion fruit (*Passiflora* spp.), guava (*Psidium* spp.), thimbleberry (*Rubus rosaefolius*), and popolo (*Solanum nodiflorum*). In sugarcane fields, sugarcane comprises about 70% of their diet by volume, while in surrounding noncrop gulches, it comprises about 20% to 50%. Rats cannot subsist on sugarcane alone. They need additional protein, such as earthworms, spiders, amphipods, insects, and eggs and young of ground-nesting birds.

General Biology, Reproduction, and Behavior

Reproduction varies among geographic areas and is influenced by weather, availability of food, and other factors. Reproductive activity of Polynesian rats on Oahu reaches a peak in late summer and ceases in mid to late winter. Polynesian rats on Kure Atoll in northwestern Hawaii produce most litters from May through August. On the windward side of the island of Hawaii, Polynesian rats breed throughout the year, with peak reproduction occurring in the summer and early fall. Females have an average of 4 litters per year, with a range of 3 to 6 and an average of 4 young per litter. The minimum gestation period for captive rats is 23 days, with lactation prolonging gestation by 3 to 7 days. In captivity, newborns open their eyes about 2 weeks after birth and are weaned when about 3 weeks old. Captive-bred individuals reach reproductive maturity when they are 60 to 70 days old and weigh about 1.5 ounces (40 g). The life expectancy of wild rats is less than 1 year.

Hawaii is one of the few areas in the world where sugarcane is grown as a 2- to 3-year crop. Most rats living in cane fields either die or migrate to surrounding areas during harvest, and populations do not rebuild until the second half of the crop cycle. During much of the first year, the sugarcane stalks stand erect, the crop canopy is open, and most fields have little ground cover. Some rats from adjacent waste areas forage along the periphery of young sugarcane fields, but few venture into the interior until the sugarcane is 8 to 12 months of age. At this time the sugarcane stalks fall over and dead leaves accumulate. The resulting thatch layer is rich in invertebrate food and provides protective cover in fields where rats establish dens.

Movements and home ranges in sugarcane fields vary depending on population density, crop age, and other factors. Polynesian rats are nocturnal and are relatively sedentary. Males travel farther than females, but the home ranges of both sexes decrease as the sugarcane matures. Individuals typically stray less than 100 to 165 feet (30 to 50 m) from their burrows.

Population Changes

Roof rats, Norway rats, and Polynesian rats coexist throughout much of the Pacific basin. It is not known how much, if any, interspecific competition exists. After the arrival of Norway rats, roof rats, and house mice (*Mus musculus*) in New Zealand, populations of Polynesian rats declined. Today, they are very rare on the two main islands. It is not clear whether a similar decline occurred in Hawaii, but if so, Polynesian rats have adjusted. Today, they are the most abundant lowland rat in many parts of the state.

In Hawaii, roof rats, Norway rats, and Polynesian rats often occur in the same sugarcane fields. Only the latter two are major pests in sugarcane, with roof rats occurring mostly near field edges. Since the late 1960s Norway rats have increased their abundance relative to the other two species in Hawaiian sugarcane fields and are now the species of primary concern to the Hawaiian sugarcane industry. Polynesian rats, however, are still locally abundant in many fields.

Damage and Damage Identification

Polynesian rats are a major agricultural pest throughout Southeast Asia and the Pacific region. Crops damaged by this species include rice, maize, sugarcane, coconut, cacao, pineapple, and root crops. In the United States, sugarcane is the only crop of economic concern damaged by Polynesian rats. The most severe damage is to unirrigated sugarcane on the windward side of the islands of Hawaii and Kauai. Here, rats find excellent habitat in the lush vegetation of noncrop lands adjacent to sugarcane fields.

Rat damage to Hawaiian sugarcane is negligible until the crop is 14 to 15 months old, after which it increases substantially and progressively until harvest. Damage caused by roof rats, Norway rats, and Polynesian rats is

very similar. All three species chew on the internodes of growing stalks. Injury ranges from barely perceptible nicks in the outer rind to neatly chiseled canoe-shaped cavities. Small chips usually are evident on the ground where rats have fed. Rat depredation can be distinguished easily from that of feral pigs (*Sus scrofa*). Pigs chew on the entire stalk, leaving it with a shredded appearance. Trampled vegetation is further evidence of pig activity.

Legal Status

Rats are an exotic species in Hawaii and are not protected by law. They may be controlled by any method consistent with state and federal laws and regulations.

Damage Prevention and Control Methods

Exclusion

Electric fences and physical barriers have been used to prevent rats from entering experimental farm plots. It is questionable, however, whether current fencing designs and exclusion techniques are practical for Hawaiian sugarcane fields.

Cultural Methods

Advancing harvest from the usual 22- to 24-month schedule would reduce losses. Adoption of a shorter crop cycle, however, would increase planting and harvesting costs and probably would not be feasible considering current economic conditions. Synchronized planting and harvesting of adjacent fields might reduce movements of rats from recently harvested fields into younger fields. Modification or elimination of noncrop vegetation adjacent to sugarcane fields would help reduce invasion from surrounding areas. Cattle grazing or commercial production of trees for energy or timber might reduce the vegetative understory in such areas. Herbicide use probably is not economical or environmentally desirable.

Development of sugarcane varieties that are less susceptible to damage by rats is a promising avenue for research. Possible selection criteria include rind hardness, stalk diameter, degree and time of lodging, resistance to souring, and potential for compensatory growth.

Fig. 2. Rat-damaged sugarcane

Repellents

None are registered.

Toxicants

Zinc phosphide is the only toxicant registered in the United States for rat control in sugarcane. Baits are formulated either as pellets or on oats and usually are broadcast by fixed-wing aircraft at the rate of 5 pounds per acre (5.6 kg/ha). A maximum of four applications and 20 pounds per acre (22.4 kg/ha) may be applied per crop cycle.

Zinc phosphide baits in Hawaii are most effective against Polynesian rats and least effective against Norway rats. Because the relative abundances of the two species vary substantially from field to field and may shift as the crop matures, the efficacy of zinc phosphide baits also varies. Where Norway rat populations increase during the second year of the crop cycle, zinc phosphide baits become progressively less effective.

Fumigants

None are registered for the control of Polynesian rats in Hawaii.

Trapping

Polynesian rats can be captured easily with coconut bait and standard snap traps, modified wire-cage Japanese live traps, or other appropriate traps.

However, trapping in sugarcane fields is extremely labor intensive and is not practical for control purposes. Plantation personnel took an average of 141,000 rats annually from sugarcane fields on the island of Hawaii during the early 1900s, but with no apparent effect either on rat populations or on sugarcane damage (Pemberton 1925).

Shooting

This is not a practical form of population control.

Biological Control

In 1883, the Indian mongoose (*Herpestes auropunctatus*) was introduced into Hawaii from the West Indies to help control rats on sugarcane plantations, and today they are common on all the major islands except Kauai. Although mongooses are diurnal and rats are nocturnal, rodents comprise the major portion of the mongoose's diet in and around sugarcane fields. Pemberton (1925) found parts of rodents in 88% of 356 mongoose pellets collected in sugarcane fields, with 52% of all samples containing nothing but rodent parts. Kami (1964) reported that 72% of 393 mongoose scats collected along dirt roads adjacent to cane fields contained rodent pelage and bones. However, rats reproduce rapidly and continue to thrive and cause major economic damage in Hawaii. Not only has the introduction of the mongoose failed to control rat populations, but it has resulted in unforeseen ecological effects. Mongoose predation has been implicated in the decline of the Hawaiian goose (*Nesochen sandvicensis*), Newell's shearwater (*Puffinus newelli*), and other ground-nesting birds in Hawaii. If rabies ever becomes established in Hawaii, the mongoose is likely to become a public health concern.

Between 1958 and 1961, barn owls (*Tyto alba*) also were introduced into the state to help control rodent agricultural pests. This species and the native short-eared owl (*Asio flammeus*) subsist in Hawaii in large part on rodents. Although raptors sometimes are attracted to rats fleeing recently harvested sugarcane fields, heavy thatch prevents their foraging in maturing sugarcane fields.

Dogs have also been used to control rats in harvested sugarcane fields (Pemberton 1925, Doty 1945), but controls applied after harvest are likely to have little effect on damage or yields.

Economics of Damage and Control

In addition to direct losses, secondary infections of stalks by insects and pathogens result in additional losses of stalks and deterioration of cane juice. The economic impact of these losses fluctuates from year to year, largely dependent on the prevailing price of sugar. In 1980, when the average price of raw sugar was at a 50-year high, the Hawaiian sugarcane industry may have lost $20 million. Current losses are conservatively estimated to be greater than $6 million annually (A. Ota, Hawaiian Sugar Planters' Association, pers. commun.).

Aerially broadcasting 5 pounds of zinc phosphide-treated oats to 1 acre (5.6 kg/ha) of sugarcane costs approximately $4.99, including $3.50 for bait, $1.33 for the airplane, fuel, and pilot, and $0.16 for labor, transportation of materials, administrative overhead, and other expenses. The registration label calls for four applications during the crop cycle, which would cost about $20.00 per acre ($50.00/ha). Studies have indicated that applications of zinc phosphide reduce damage in Hawaiian sugarcane fields by as much as 30% to 45%. Thus, four applications of zinc phosphide would result in savings of $120 to $185 per acre ($296 to $475/ha), or a return of $6.00 to $9.00 for every $1.00 spent applying bait. This assumes a potential yield of 10 tons per acre (22.5 mt/ha) without applying controls, a farm price of $368 per ton ($409/mt), and a 10% decrease in yield due to rat damage. The benefits of using zinc phosphide are less in fields with lower damage.

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Editors
Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Rex E. Marsh
Specialist in Vertebrate Ecology
(retired)
Department of Wildlife, Fisheries
and Conservation Biology
University of California
Davis, California 95616

ROOF RATS

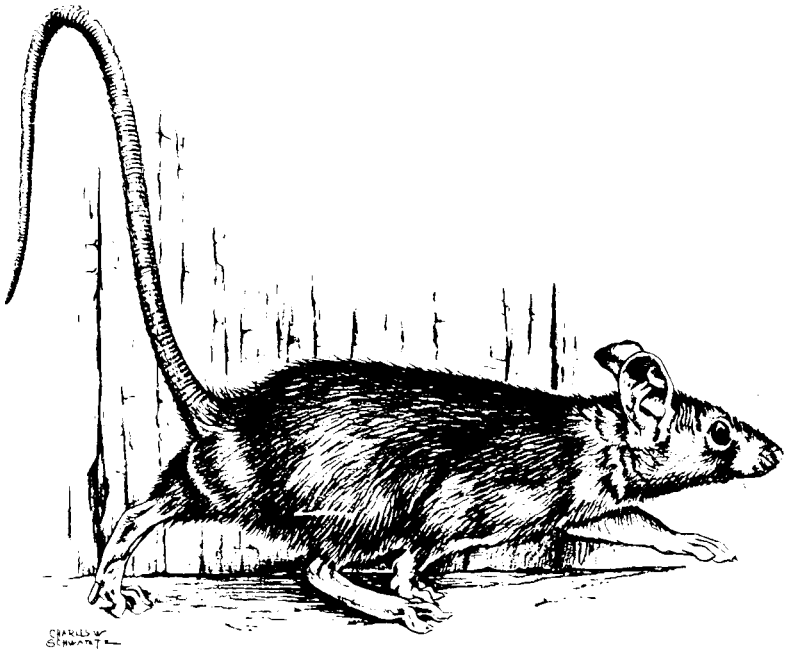


Fig. 1. Roof rat, *Rattus rattus*

Damage Prevention and Control Methods

Many control methods are essentially the same for roof rats as for Norway rats.

Exclusion and Rodent-proofing

Seal all openings that provide entry to structures.

Rat guards (for overhead utility lines).

Habitat Modification and Sanitation

Practice good housekeeping and facility sanitation.

Contain and dispose of garbage and refuse properly.

Reduce vegetative cover (for example, trim vines from buildings and fences).

Cultural practices in agriculture (weed and brush control, pruning).

Frightening

Ultrasonic devices have not been proven to provide rat control.

Lights and other sounds are of limited value.

Visual devices such as model owls, snakes, and cats are of no value.

Repellents

None are effective.

Toxicants

Anticoagulant rodenticides (slow-acting chronic-type poisons)
Brodifacoum (Talon®, Havoc®).
Bromadiolone (Maki®, Contrac®).
Chlorophacinone (RoZol®).
Diphacinone (Ramik®, Ditrac®).
Pindone (Pival®, Pivalyn®).
Warfarin (Co-Rax®).

Toxicants other than anticoagulants (may be acute or chronic poisons)
Bromethalin (Assault®, Vengeance®).
Cholecalciferol (Vitamin D_3) (Quintox®, Rampage®).
Zinc phosphide (Ridall Zinc®, ZP® Rodent Bait).

Fumigants

Structure or commodity fumigation.

Burrow fumigants are of limited use.

Trapping

Snap traps.

Box-type kill traps.

Live traps.

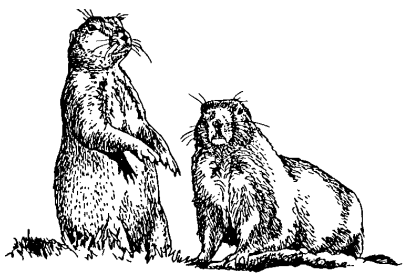
Glue boards.

Shooting

Limited usefulness where legal and not hazardous.

Predators

Cats may occasionally catch roof rats, as will barn owls. Predators are of little, if any, value in controlling roof rats.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

B-125

Identification

The roof rat (*Rattus rattus,* Fig. 1) is one of two introduced rats found in the contiguous 48 states. The Norway rat (*R. norvegicus*) is the other species and is better known because of its widespread distribution. A third rat species, the Polynesian rat (*R. exulans*) is present in the Hawaiian Islands but not on the mainland. *Rattus rattus* is commonly known as the roof rat, black rat, and ship rat. Roof rats were common on early sailing ships and apparently arrived in North America by that route. This rat has a long history as a carrier of plague.

Three subspecies have been named, and these are generally identified by their fur color: (1) the black rat (*R. rattus rattus* Linnaeus) is black with a gray belly; (2) the Alexandrine rat (*R. rattus alexandrinus* Geoffroy) has an agouti (brownish streaked with gray) back and gray belly; and (3) the fruit rat (*R. rattus frugivorus* Rafinesque), has an agouti back and white belly. The reliability of using coloration to identify the subspecies is questionable, and little significance can be attributed to subspecies differentiations. In some areas the subspecies are not distinct because more than one subspecies has probably been introduced and cross-breeding among them is a common occurrence. Roof rats cannot, however, cross with Norway rats or any native rodent species.

Fig. 2. Approximate distribution of roof rats (a) and Norway rats (b) in the United States.

Some of the key differences between roof and Norway rats are given in Table 1. An illustration of differences is provided in figure 2 of the chapter on Norway rats.

Range

Roof rats range along the lower half of the East Coast and throughout the Gulf States upward into Arkansas. They also exist all along the Pacific Coast and are found on the Hawaiian Islands (Fig. 2). The roof rat is more at home in warm climates, and apparently less adaptable, than the Norway rat, which is why it has not spread throughout the country. Its worldwide geographic distribution suggests that it is much more suited to tropical and semitropical climates. In rare instances, isolated populations are found in areas not within their normal distribution range in the United States. Most of the states in the US interior are free of roof rats, but isolated infestations, probably stemming from infested cargo shipments, can occur.

Habitat

Roof rats are more aerial than Norway rats in their habitat selection and often live in trees or on vine-covered fences. Landscaped residential or industrial areas provide good habitat, as does riparian vegetation of riverbanks and streams. Parks with natural and artificial ponds, or reservoirs may also be infested. Roof rats will often move into sugarcane and citrus groves. They are sometimes found living in rice fields or around poultry or other farm buildings as well as in industrial sites where food and shelter are available.

Table 1. Identifying characteristics of adult rats.

Item	Roof Rat (*Rattus rattus*)	Norway Rat (*Rattus norvegicus*)
General appearance	Sleek, graceful	Large, robust
Color of belly	Uniform: all white, all buff, or all gray	White with gray underfur
Body weight	5 to 10 ounces (150 to 250 g)	7 to 18 ounces (200 to 500 g)
Tail	4.3 inches (more than 11 cm), extends at least to snout; black, fine scales	4.3 inches (more than 11 cm), shorter than body; dark above, pale below
Head	Muzzle pointed	Muzzle blunt
Ears	Can be pulled over eyes	Do not reach eyes
Hind foot length	1.3 inches (3.5 cm)	1.7 inches (4.4 cm)
Number of teats on female	10	12

Roof rats frequently enter buildings from the roof or from accesses near overhead utility lines, which they use to travel from area to area. They are often found living on the second floor of a warehouse in which Norway rats occupy the first or basement floor. Once established, they readily breed and thrive within buildings, just as Norway rats do. They have also been found living in sewer systems, but this is not common.

Food Habits

The food habits of roof rats outdoors in some respects resemble those of tree squirrels, since they prefer a wide variety of fruit and nuts. They also feed on a variety of vegetative parts of ornamental and native plant materials. Like Norway rats, they are omnivorous and, if necessary, will feed on almost anything. In food-processing and storage facilities, they will feed on nearly all food items, though their food preferences may differ from those of Norway rats. They do very well on feed provided for domestic animals such as swine, dairy cows, and chickens, as well as on dog and cat food. There is often a correlation between rat problems and the keeping of dogs, especially where dogs are fed outdoors. Roof rats usually require water daily, though their local diet may provide an adequate amount if it is high in water content.

General Biology

Control methods must reflect an understanding of the roof rat's habitat requirements, reproductive capabilities, food habits, life history, behavior, senses, movements, and the dynamics of its population structure. Without this knowledge, both time and money are wasted, and the chances of failure are increased.

Unfortunately, the rat's great adaptability to varying environmental conditions can sometimes make this information elusive.

Reproduction and Development

The young are born in a nest about 21 to 23 days after conception. At birth they are hairless, and their eyes are closed. The 5 to 8 young in the litter develop rapidly, growing hair within a week. Between 9 and 14 days, their eyes open, and they begin to explore for food and move about near their nest. In the third week they begin to take solid food. The number of litters depends on the area and varies with nearness to the limit of their climatic range, availability of nutritious food, density of the local rat population, and the age of the rat. Typically, 3 or more litters are produced annually.

The young may continue to nurse until 4 or 5 weeks old. By this time they have learned what is good to eat by experimenting with potential food items and by imitating their mother.

Young rats generally cannot be trapped until about 1 month old. At about 3 months of age they are completely independent of the mother and are reproductively mature.

Breeding seasons vary in different areas. In tropical or semitropical regions, the season may be nearly year-round. Usually the peaks in breeding occur in the spring and fall. Roof rats prefer to nest in locations off of the ground and rarely dig burrows for living quarters if off-the-ground sites exist.

Feeding Behavior

Rats usually begin searching for food shortly after sunset. If the food is in an exposed area and too large to be eaten quickly, but not too large to be moved, they will usually carry it to a hiding place before eating it. Many rats may cache or hoard considerable amounts of solid food, which they eat later. Such caches may be found in a dismantled wood pile, attic, or behind boxes in a garage.

When necessary, roof rats will travel considerable distances (100 to 300 feet [30 to 90 m]) for food. They may live in the landscaping of one residence and feed at another. They can often be seen at night running along overhead utility lines or fences. They may live in trees, such as palm, or in attics, and climb down to a food source. Traditional baiting or trapping on the ground or floor may intercept very few roof rats unless bait and/or traps are placed at the very points that rats traverse from above to a food resource. Roof rats have a strong tendency to avoid new objects in their environment and this neophobia can influence control efforts, for it may take several days before they will approach a bait station or trap. Neophobia is more pronounced in roof rats than in Norway rats. Some roof rat populations are skittish and will modify their travel routes and feeding locations if severely and frequently disturbed. Disturbances such as habitat modifications should be avoided until the population is under control.

Senses

Rats rely more on their keen senses of smell, taste, touch, and hearing than on vision. They are considered to be color-blind, responding only to the degree of lightness and darkness of color.

They use their keen sense of smell to locate and select food items, identify territories and travel routes, and recognize other rats, especially those of the opposite sex. Taste perception of rats is good; once rats locate food, the taste will determine their food preferences.

Touch is an important sense in rats. The long, sensitive whiskers (vibrissae) near their nose and the guard hairs on their body are used as tactile sensors. The whiskers and guard hairs enable the animals to travel adjacent to walls in the dark and in burrows.

Roof rats also have an excellent sense of balance. They use their tails for balance while traveling along overhead utility lines. They move faster than Norway rats and are very agile climbers, which enables them to quickly escape predators. Their keen sense of hearing also aids in their ability to detect and escape danger.

Social Behavior

The social behavior of free-living roof rats is very difficult to study and, as a result, has received less attention than that of Norway rats. Most information on this subject comes from populations confined in cages or outdoor pens.

Rats tend to segregate themselves socially in both space and time. The more dominant individuals occupy the better habitats and feed whenever they like, whereas the less fortunate individuals may have to occupy marginal habitat and feed when the more dominant rats are not present.

Knowledge is limited on interspecific competition between the different genera and species of rats. At least in some parts of the United States and elsewhere in the world, the methods used to control rats have reduced Norway rat populations but have permitted roof rats to become more prominent, apparently because they are more difficult to control. Elsewhere, reports indicate that roof rats are slowly disappearing from localized areas for no apparent reason.

It has often been said that Norway rats will displace roof rats whenever they come together, but the evidence is not altogether convincing.

Population Dynamics

Rat densities (numbers of rats in a given area) are determined primarily by the suitability of the habitat—the amount of available nutritional and palatable food and nearby protective cover (shelter or harborage).

The great adaptability of rats to human-created environments and the high fertility rate of rats make for quick recuperation of their populations. A control operation, therefore, must reduce numbers to a very low level; otherwise, rats will not only reproduce rapidly, but often quickly exceed their former density for a short period of time.

Unless the suitability of the rat's habitat is destroyed by modifying the landscaping, improving sanitation, and rat-proofing, control methods must be unrelenting if they are to be effective.

Damage and Damage Identification

Nature of Damage

In food-processing and food-storage facilities, roof rats do about the same type of damage as Norway rats, and damage is visually hard to differentiate. In residences where rats may be living in the attic and feeding outdoors, the damage may be restricted to tearing up insulation for nesting or gnawing electrical wiring. Sometimes rats get into the kitchen area and feed on stored foods. If living under a refrigerator or freezer, they may disable the unit by gnawing the electrical wires. In landscaped yards they often live in overgrown shrubbery or vines, feeding on ornamentals, vegetables, fruits, and nuts. Snails are a favorite food, but don't expect roof rats to eliminate a garden snail problem. In some situations, pet food and poorly managed garbage may represent a major food resource.

In some agricultural areas, roof rats cause significant losses of tree crops such as citrus and avocados and, to a lesser extent, walnuts, almonds, and other nuts. They often eat all the pulp from oranges while the fruit is still hanging on the tree, leaving only the empty rind. With lemons they may eat only the rind and leave the hanging fruit intact. They may eat the bark of smaller citrus branches and girdle them. In sugarcane, they move into the field as the cane matures and feed on the cane stalks. While they may not kill the stalk outright, secondary organisms generally invade and reduce the sugar quality. Norway rats are a common mammalian pest of rice, but sometimes roof rats also feed on newly planted seed or the seedling as it emerges. Other vegetable, melon, berry, and fruit crops occasionally suffer relatively minor damage when adjacent to infested habitat such as riparian vegetation.

Like the Norway rat, the roof rat is implicated in the transmission of a number of diseases to humans, including murine typhus, leptospirosis, salmonellosis (food poisoning), rat-bite fever, and plague. It is also capable of transmitting a number of diseases to domestic animals and is suspected in the transference of ectoparasites from one place to another.

Rat Sign

The nature of damage to outdoor vegetation can often provide clues as to whether it is caused by the roof or Norway rat. Other rat signs may also assist, but be aware that both species may be present. Setting a trap to collect a few specimens may be the only sure way to identify the rat or rats involved. Out-of-doors, roof rats may be present in low to moderate numbers with little sign in the way of tracks or droppings or runs and burrows.

There is less tendency to see droppings, urine, or tracks on the floor in buildings because rats may live overhead between floors, above false ceilings, or in utility spaces, and venture down to feed or obtain food. In food-storage facilities, the most prominent sign may be smudge marks, the result of oil and dirt rubbing off of their fur as they travel along their aerial routes.

The adequate inspection of a large facility for the presence and location of roof rats often requires a nighttime search when the facility is normally shut down. Use a powerful flashlight to spot rats and to determine travel routes for the best locations to set baits and traps. Sounds in the attic are often the first indication of the presence of roof rats in a residence. When everyone is asleep and the house is quiet, the rats can be heard scurrying about.

Legal Status

Roof rats are not protected by law and can be controlled any time with mechanical or chemical methods. Pesticides must be registered for rat control by federal and/or state authorities and used in accordance with label directions.

Damage Prevention and Control Methods

The damage control methods used for roof rats are essentially the same as for Norway rats. However, a few differences must be taken into account.

Exclusion or Rodent-proofing

When rodent-proofing against roof rats, pay close attention to the roof and roof line areas to assure all accesses are closed. Plug or seal all openings of greater than 1/2 inch (1.3 cm) diameter with concrete mortar, steel wool, or metal flashing. Rodent-proofing against roof rats usually requires more time to find entry points than for Norway rats because of their greater climbing ability. Eliminate vines growing on buildings and, when feasible, overhanging tree limbs that may be used as travel routes. For more detailed information, see **Rodent-proof Construction and Exclusion Methods.**

Attach rat guards to overhead utility wires and maintain them regularly. Rat guards are not without problems, however, because they may fray the insulation and cause short circuits.

Habitat Modification and Sanitation

The elimination of food and water through good warehouse sanitation can do much to reduce rodent infestation. Store pet food in sealed containers and do not leave it out at night. Use proper garbage and refuse disposal containers and implement exterior sanitation programs. Emphasis should be placed on the removal of as much harborage as is practical. For further information see **Norway Rats.**

Dense shrubbery, vine-covered trees and fences, and vine ground cover make ideal harborage for roof rats. Severe pruning and/or removal of certain ornamentals are often required to obtain a degree of lasting rat control. Remove preharvest fruits or nuts that drop in backyards. Strip and destroy all unwanted fruit when the harvest period is over.

In tree crops, some cultural practices can be helpful. When practical, remove extraneous vegetation adjacent to the crop that may provide shelter for rats. Citrus trees, having very low hanging skirts, are more prone to damage because they provide rats with protection. Prune to raise the skirts and remove any nests constructed in the trees. A vegetation-free margin around the grove will slow rat invasions because rats are more susceptible to predation when crossing unfamiliar open areas.

Frightening

Rats have acute hearing and can readily detect noises. They may be frightened by sound-producing devices for awhile but they become accustomed to constant and frequently repeated sounds quickly. High-frequency sound-producing devices are advertised for frightening rats, but almost no research exists on their effects specifically on roof rats. It is unlikely, however, they will be any more effective for roof rats than for Norway rats. These devices must be viewed with considerable skepticism, because research has not proven them effective.

Lights (flashing or continuously on) may repel rats at first, but rats will quickly acclimate to them.

Repellents

Products sold as general animal repellents, based on taste and/or odor, are sometimes advertised to repel animals, including rats, from garbage bags. The efficacy of such products for rats is generally lacking. No chemical repellents are specifically registered for rat control.

Toxicants

Rodenticides were once categorized as acute (single-dose) or chronic (multiple-dose) toxicants. However, the complexity in mode of action of newer materials makes these classifications outdated. A preferred categorization would be "anticoagulants" and "non-anticoagulants" or "other rodenticides."

Anticoagulants (slow-acting, chronic toxicants). Roof rats are susceptible to all of the various anticoagulant rodenticides, but less so than Norway rats. Generally, a few more feedings are necessary to produce death with the first-generation anticoagulants (warfarin, pindone, diphacinone, and chlorophacinone) but this is less significant with the second-generation anticoagulants (bromadiolone and brodifacoum). All anticoagulants provide excellent roof rat control when prepared in acceptable baits. A new second-generation anticoagulant, difethialone, is presently being developed and EPA registration is anticipated in the near future. For the characteristics of the various anticoagulant rodenticides see **Norway Rats.**

A few instances of first-generation anticoagulant resistance have been reported in roof rats; although not common, it may be underestimated because so few resistance studies have been conducted on this species. Resistance is of little consequence in the control of roof rats, especially with the newer rodenticides presently available. Where anticoagulant resistance is known or suspected, the use of first-generation anticoagulants should be avoided in favor of the second-generation anticoagulants or one of the nonanticoagulant rodenticides like bromethalin or cholecalciferol.

Other rodenticides. The older rodenticides, formerly referred to as acute toxicants, such as arsenic, phosphorus, red squill, and ANTU, are either no longer registered or of little importance in rat control. The latter two were ineffective for roof rats. Newer rodenticides are much more efficacious and have resulted in the phasing out of these older materials over the last 20 years.

At present there are three rodenticides—zinc phosphide, cholecalciferol (vitamin D_3), and bromethalin—registered and available for roof rat control. Since none of these are anticoagulants, all can be used to control anticoagulant-resistant populations of roof rats.

Roof rats can be controlled with the same baits used for Norway rats. Most commercial baits are registered for both species of rats and for house mice, but often they are less acceptable to roof rats than to the other species. For best results, try several baits to find out which one rats consume most. No rat bait ingredient is universally highly acceptable, and regional differences are the rule rather than the exception.

Pelleted or loose cereal anticoagulant baits are used extensively in tamper-resistant bait boxes or stations for a permanent baiting program for Norway rats and house mice. They may not be effective on roof rats, however, because of their usual placement. Bait stations are sometimes difficult to place for roof rat control because of the rodents' overhead traveling characteristics. Anticoagulant paraffin-type bait blocks provide an alternative to bait stations containing pelleted or loose cereal bait. Bait blocks are easy to place in small areas and difficult-to-reach locations out of the way of children, pets, and nontarget species. Where label instructions permit, small blocks can be placed or fastened on rafters, ledges, or even attached to tree limbs, where they are readily accessible to the arboreal rats.

Some of the first-generation anticoagulants (pindone and warfarin) are available as soluble rodenticides from which water baits can be prepared. Liquid baits may be an effective alternative in situations where normal baits are not readily accepted, especially where water is scarce or where rats must travel some distance to reach water.

In controlling roof rats with rodenticides, a sharp distinction must be made between control in and around buildings and control away from buildings such as in landfills and dumps, along drainage ditches and streams, in sewer water evaporation ponds, and in parks. Control of roof rat damage in agriculture represents yet another scenario. Distinctions must be made as to which rodenticide (registered product) to use, the method of application or placement, and the amount of bait to apply. For example, only zinc phosphide can be applied on the ground to control rats in sugarcane or macadamia orchards, and the second-generation anticoagulants, cholecalciferol and bromethalin, can be used only in and around buildings, not around crops or away from buildings even in noncrop situations. Selection of rodenticides and bait products must be done according to label instructions. Labels will specify where and under what conditions the bait can be used. Specifications may vary depending on bait manufacturer even though the active ingredient may be the same. The product label is the law and dictates the product's location of use and use patterns.

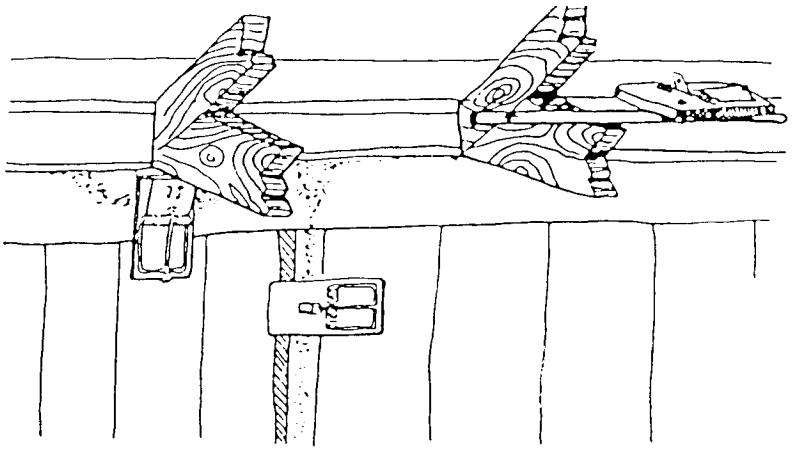


Fig. 3. Overhead trap sets are particularly useful for roof rats. Trap at left is modified by fastening a piece of cardboard to expand its trigger size (traps with expanded treadles can also be purchased from several manufacturers). Traps may be nailed to beams or studs and secured to pipes with wires.

Tracking powders. Tracking powders play an important role in structural rodent control. They are particularly useful for house mouse control in situations where other methods seem less appropriate. Certain first-generation anticoagulants are registered as tracking powders for roof rat control; however, none of the second generation materials are so registered. Their use for roof rats is limited to control within structures because roof rats rarely produce burrows.

Tracking powders are used much less often for roof rats than for Norway rats because roof rats frequent overhead areas within buildings. It is difficult to find suitable places to lay the tracking powder that will not create a potential problem of contaminating food or materials below the placement sites.

Tracking powders can be placed in voids behind walls, near points of entry, and in well-defined trails. Tunnel boxes or bait boxes specially designed to expose a layer of toxic powder will reduce potential contamination problems and may actually increase effectiveness. Some type of clean food can be used to entice the rats to the boxes, or the tracking powders can be used in conjunction with an anticoagulant bait, with both placed in the same station.

Fumigants

Since roof rats rarely dig burrows, burrow fumigants are of limited use; however, if they have constructed burrows, then fumigants that are effective on Norway rats, such as aluminum phosphide and gas cartridges, will be effective on roof rats. Where an entire warehouse may be fumigated for insect control with a material such as methyl bromide, all rats and mice that are present will be killed. The fumigation of structures, truck trailers, or rail cars should only be done by a licensed pest control operator who is trained in fumigation techniques. Rodent-infested pallets of goods can be tarped and fumigated on an individual or collective basis.

Trapping

Trapping is an effective alternative to pesticides and recommended in some situations. It is recommended for use in homes because, unlike with poison baits, there is no risk of a rat dying in an inaccessible place and creating an odor problem.

The common wooden snap traps that are effective for Norway rats are effective for roof rats. Raisins, prunes, peanut butter, nutmeats, and gumdrops make good baits and are often better than meat or cat food baits. The commercially available, expanded plastic treadle traps, such as the Victor Professional Rat Trap, are particularly effective if properly located in well-traveled paths. They need not be baited. Place traps where they will intercept rats on their way to food, such as on overhead beams, pipes, ledges, or sills frequently used as travel routes (Fig. 3). Some traps should be placed on the floor, but more should be placed above floor level (for example, on top of stacked commodities). In homes, the attic and garage rafters close to the infestation are the best trapping sites.

Pocket gopher box-type traps (such as the DK-2 Gopher Getter) can be modified to catch rats by reversing the action of the trigger. Presently, only one such modified trap (Critter Control's Custom Squirrel & Rat Trap) is commercially available. These kill traps are often baited with whole nuts and are most useful in trapping rats in trees. Their design makes them more rat-specific when used out-of-doors than ordinary snap traps that sometimes take birds. Caution should be taken to avoid trapping nontarget species such as tree squirrels.

Wire-mesh, live traps (Tomahawk®, Havahart®) are available for trapping rats. Rats that are captured should be humanely destroyed and not released elsewhere because of their role in disease transmission, damage potential, and detrimental effect on native wildlife.

Glue boards will catch roof rats, but, like traps, they must be located on beams, rafters, and along other travel routes, making them more difficult to place effectively for roof rats than for Norway rats or house mice. In general, glue boards are more effective for house mice than for either of the rat species.

Shooting

Where legal and not hazardous, shooting of roof rats is effective at dusk as they travel along utility lines. Air rifles, pellet guns, and .22-caliber rifles loaded with bird shot are most often used. Shooting is rarely effective by itself and should be done in conjunction with trapping or baiting programs.

Predators

In urban settings, cats and owls prey on roof rats but have little if any effect on well-established populations. In some situations in which the rats have been eliminated, cats that are good hunters may prevent reinfestation.

In agricultural settings, weasels, foxes, coyotes, and other predators prey on roof rats, but their take is inconsequential as a population control factor. Because roof rats are fast and agile, they are not easy prey for mammalian or avian predators.

Economics of Damage and Control

Roof rats undoubtedly cause millions of dollars a year in losses of food and feed and from damaging structures and other gnawable materials. On a nationwide basis, roof rats cause far less economic loss than Norway rats because of their limited distribution.

There are approximately 30,000 professional structural pest control operators in the United States and about 70% of these are primarily involved in general pest control, which includes rodent control. It is difficult to estimate how much is spent in structural pest control specifically for roof rats because estimates generally group rodents together.

Sugarcane, citrus, avocados, and macadamia nuts are the agricultural crops that suffer the greatest losses. In Hawaii, annual macadamia loss has recently been estimated at between $2 million and $4 million.

Acknowledgments

I wish to acknowledge my colleague, Dr. Walter E. Howard, for information taken from his publication *The Rat: Its Biology and Control,* Division of Agricultural Sciences, University of California, Leaflet 2896 (30 pp.), coauthored with R. E. Marsh. I also wish to express my thanks to Dr. Robert Timm, who authored the chapter on Norway rats. To avoid duplication of information, this chapter relies on the more detailed control methods presented in the chapter **Norway Rats.**

Figure 1 from C. W. Schwartz and E. R. Schwartz (1981). *The Wild Mammals of Missouri,* rev. ed. Univ. Missouri Press, Columbia. 356 pp.

Figures 2 and 3 from Howard and Marsh (1980), adapted by David Thornhill.

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Terrell P. Salmon
Wildlife Extension Specialist
Department of Wildlife, Fisheries
and Conservation Biology
University of California
Davis, California 95616

W. Paul Gorenzel
Staff Research Associate
Department of Wildlife, Fisheries
and Conservation Biology
University of California
Davis, California 95616

WOODRATS

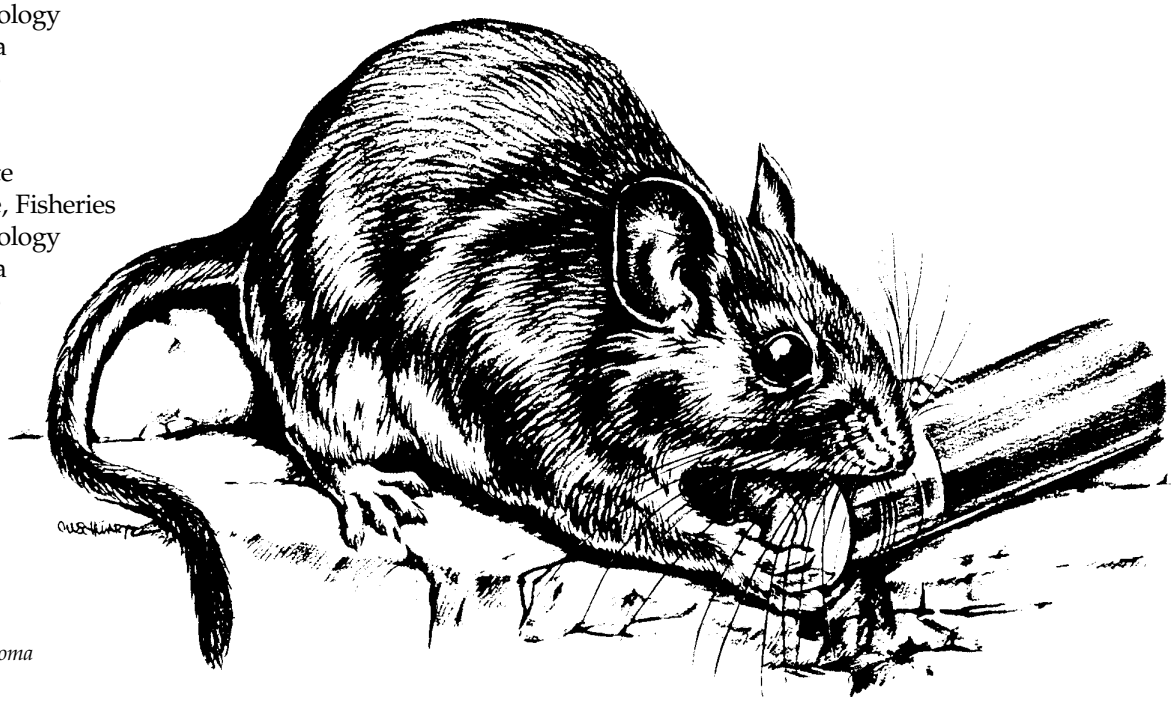


Fig. 1. Eastern woodrat, *Neotoma floridana*

Damage Prevention and Control Methods

Exclusion

Woodrats can be permanently excluded from buildings.

Cultural Methods

Not generally useful.

Trim lower branches of citrus trees.

Repellents

None are registered or considered effective at this time.

Toxicants

Anticoagulants (registered in some states).

Zinc phosphide (registered in some states).

Fumigants

Not useful.

Trapping

Rat snap trap.

Live traps.

Burrow-entrance traps.

Glue boards.

Shooting

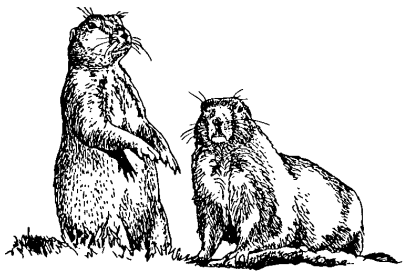
Limited usefulness.

Other Control Methods

Destruction of dens.

Identification

Eight species of woodrats (genus *Neotoma*) occur in North America (Table 1). Locally known as pack rats or trade rats, these rodents are about the size of the common Norway rat. They are distinguishable from Norway rats by their hairy rather than scaly tail, soft, fine fur, and large ears. They usually have light-colored feet and bellies.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

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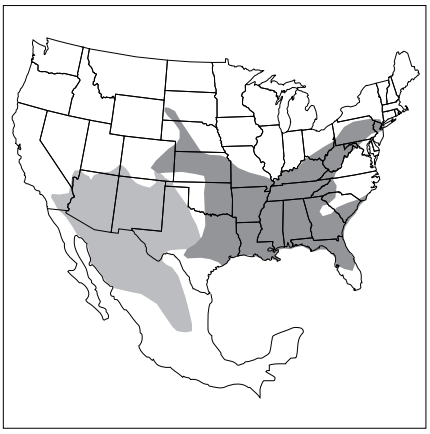

Fig. 2. Range of the eastern (dark) and whitethroat woodrats (light) in North America.

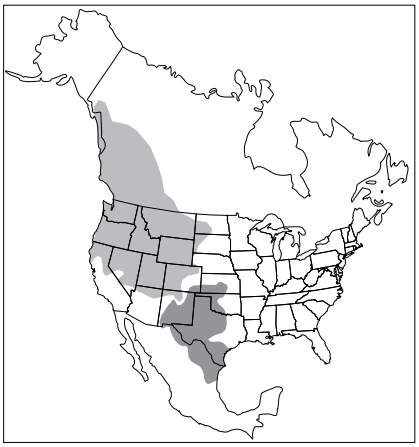

Fig. 3. Range of the southern plains (dark) and bushytail woodrats (light) in North America.

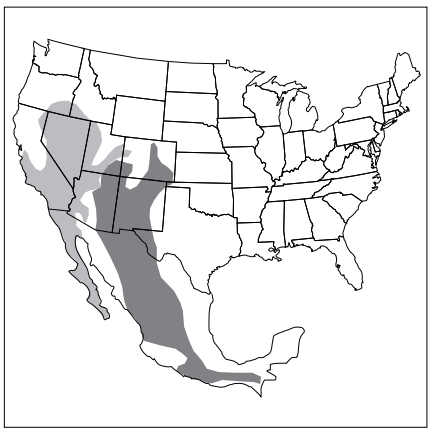

Fig. 4. Range of the Mexican (dark) and desert woodrats (light) in North America.

Range

The ranges occupied by woodrats are shown in figures 2, 3, 4, and 5.

Habitat

Each species of woodrat is generally restricted to a given type of habitat within its range. Woodrats occur from low, hot, dry deserts to cold, rocky slopes above timberline (Table 1).

Food Habits

The food habits of woodrats are relatively specific for the individual species. Species such as the bushytail woodrat, for example, feed primarily on green vegetation, twigs, and shoots, whereas the Mexican woodrat feeds on seeds, fruits, acorns, and cactus (Table 1). Woodrats may also be attracted to human food supplies in buildings. When nesting inside buildings, woodrats usually continue to

Fig 5. Range of the dusky-footed (dark) and Stephens woodrats (light) in North America.

Table 1. Woodrats (*Neotoma* spp.) in North America.

Species: Eastern woodrat (*Neotoma floridana*)
Description: Total length 14 to 17 inches (36 to 43 cm). Large grayish-brown woodrat with white or grayish belly. Tail shorter than head and body.
Habitat Preference: Rocky cliffs and mountain regions. Usually builds a home of sticks and debris.
Food Preference: Seeds, nuts, and fruits.

Species: Southern plains woodrat (*Neotoma micropus*)
Description: Total length 13 to 14 inches (33 to 36 cm). Steel-gray woodrat with white hairs on throat, breast, and feet. Blackish tail.
Habitat Preference: Semi-arid brushland, low valleys, and plains.
Food Preference: Cactus, seeds, and acorns.

Species: Whitethroat woodrat (*Neotoma albigula*)
Description: Total length 13 to 15 inches (33 to 38 cm). Body is gray, belly is white. Hairs on throat and feet white. Tail whitish to brown.
Habitat Preference: Brushlands and rocky cliffs with shallow caves. Builds a house 2 to 3 feet (0.6 to 0.9 m) high made of sticks and rocks.
Food Preference: Cactus, beans and seeds, leaves of plants, especially new growth.

Species: Desert woodrat (*Neotoma lepida*)
Description: Total length 10 to 13 inches (25 to 33 cm). Body pale to dark gray washed with fulvous. Belly grayish to fulvous. Slate gray at base of hairs.
Habitat Preference: Desert floors or rocky slopes. House usually on ground or along cliffs.
Food Preference: Seeds, fruits, acorns, and cactus.

Species: Stephens woodrat (*Neotoma stephensi*)
Description: Total length 10 to 14 inches (25 to 36 cm). Body grayish buff, darker on top, belly washed with buff. Dusky wedge on top hind foot. Tail slightly bushy on end, whitish below, blackish above.
Habitat Preference: Juniper woodlands.
Food Preference: Primarily juniper.

Species: Mexican woodrat (*Neotoma mexicana*)
Description: Total length 12 to 13 inches (30 to 33 cm). Gray to black in color. Tail distinctly bicolored with white below, black above.
Habitat Preference: Rocks and cliffs in mountains. Does not normally build houses.
Food Preference: Acorns, nuts, seeds, fruits, and cactus plants.

Species: Dusky-footed woodrat (*Neotoma fuscipes*)
Description: Total length 14 to 18 inches (36 to 46 cm). Body gray-brown above, gray to white below. Tail slightly paler below. Dusky hairs sprinkled on hind feet.
Habitat Preference: Dense chaparral, riparian thickets, deciduous or mixed woodlands. Builds large stick houses on ground or in trees.
Food Preference: Variety of seeds, nuts, acorns, fruits, green vegetation, and fungi.

Species: Bushytail woodrat (*Neotoma cinera*)
Description: Total length 15 to 16 inches (38 to 41 cm). Body varies from pale gray to nearly black. Has a long, bushy squirrel-like tail.
Habitat Preference: High mountains. Climbs about cliffs easily. Does not normally build houses.
Food Preference: Green vegetation, twigs, and shoots.

feed outside. Trails 3 to 4 inches (8 to 10 cm) wide from the building to the outside may be visible.

General Biology, Reproduction, and Behavior

Woodrats climb readily and are usually active at night. Most species build a large stick den or house on the ground or in trees, but some species live in rocky outcroppings. These houses are typically occupied by one individual or by a female and her young. One animal may inhabit several houses. A nest, usually made of finely shredded plant material, is located within the larger house. Breeding usually occurs in the spring. Woodrats produce 1 to 4 young per litter and may produce more than 1 litter per year in the southern parts of the United States.

Damage and Damage Identification

Populations generally are fairly dispersed, but economic damage to agricultural crops can occur in limited areas. Agricultural damage results when woodrats clip small twigs and branches, and when they debark citrus and other fruit trees and seedling and sapling conifers, especially redwoods. Loss of trees can occur.

Woodrats are sometimes a nuisance around cabins, outbuildings, and other infrequently used structures or vehicles. As the name "packrat" implies, they have a tendency to pack away small objects such as jewelry, cooking and eating utensils, can tabs, and other items. At times, this behavior can become a nuisance to backpackers and others. More seriously, woodrats may also shred upholstered furniture and mattresses for lining nests, and may take up residence in parked vehicles, gnawing on wires and other mechanical components.

Woodrats can be an important factor in the transmission of certain diseases, most notably plague, where this disease occurs. Dead or dying woodrats should not be handled.

Legal Status

Woodrats are classified as nongame animals. In most states they can be taken (controlled) when they threaten or damage property. Check with your local wildlife or agriculture department for laws and regulations specific to your area. For example, the Key Largo woodrat (*Neotoma floridana smalli*) was federally listed as endangered in 1991.

Damage Prevention and Control Methods

Exclusion

When nuisance problems occur in and around buildings, exclusion is the most effective method of eliminating damage. Woodrats may be excluded from buildings by the same methods used to exclude Norway and roof rats (see **Rodent-proof Construction and Exclusion Methods**). Since several species of woodrats are agile climbers, all entrances to buildings, including those at the attic level, must be closed. Cracks and openings in building foundations, and any openings for water pipes, electric wires, sewer pipes, drain spouts, and vents must be sealed. Also check for openings in attic vents, broken roof shingles, or other gaps next to the eaves. No hole larger than 1/2 inch (1.3 cm) should be left unsealed. Make sure doors, windows, and screens fit tightly. If gnawing is a problem, edges can be covered with sheet metal. Coarse steel wool, wire screen, and lightweight sheet metal are excellent materials for plugging gaps and holes. Plastic sheeting, wood, or other less sturdy materials will likely be gnawed away. When rodent-proofing, be sure the woodrat is not trapped inside the building. One way to accomplish this is to install a temporary gravity door made of sheet metal or rigid mesh wire, hinged at the top, over entrance holes. The woodrats can push it open to exit but cannot reenter.

Repellents

Objectionable odors from substances like mothballs (naphthalene), or tacky substances, may make an enclosed area temporarily less desirable for woodrats, as for other mammals. Likewise, noxious tastes may make an item less palatable. No woodrat repellents, however, are registered by the EPA. In general, chemical repellents are not considered a practical solution to woodrat problems.

Toxicants

Toxicants available for woodrat control include anticoagulants and zinc phosphide, registered under Special Local Needs 24(c) provisions. Registered products vary among states. When using toxic baits, follow label instructions carefully.

Anticoagulants are effective for woodrat control and are especially suited for use around structures because of their low hazard to pets and children. Most baits formulated for commensal rats and house mice give effective woodrat control. Anticoagulants work by interfering with the blood-clotting mechanism. Death usually occurs 4 to 5 days after feeding on bait begins. With most anticoagulants, such as chlorophacinone or diphacinone, feeding must occur daily for 4 to 5 days. Finely ground or meal-type anticoagulant baits are recommended. Since woodrats have a tendency to pack away items, pellet bait should be avoided since it is often cached at the nest site. Cached bait is probably not effective in minimizing reinvasions of the area, so it is essentially wasted and may present hazards to nontarget species.

Anticoagulants are usually put out in bait boxes, but woodrats tend to fill boxes with sticks and other debris. Therefore, use open bait containers. Bait exposed in this manner must be placed so nontarget species, pets, and children do not have ready access to it. Access to the bait by pets can be minimized by inverting a wooden crate over the bait tray. Baiting sites should be located near existing woodrat runways, feeding sites, or nests.

Anticoagulant paraffin bait blocks have also proven valuable for woodrat control. Because of the paraffin, the bait has more resistance to molding caused by moisture and, therefore, lasts longer. These bait blocks are particularly useful in mountain cabins or other structures where woodrats gain access when the building is unoccupied. The bait block should be nailed or tied down to prevent the woodrat from packing it away. When the label permits, bait blocks may also be wired to tree limbs or other elevated locations. For additional information on anticoagulant baits see **Norway Rats, Roof Rats,** and **Vertebrate Pesticides.**

In agricultural situations, zinc phosphide is a Restricted Use Pesticide and must be applied by a certified applicator. Steam-rolled oats or oat groats treated with 2.0% zinc phosphide are generally very effective on woodrats. Usually, tablespoon (4 g) amounts are scattered in runways near the nest site. Zinc phosphide bait should be applied in late afternoon just prior to woodrats' night-time feeding. Feeding on a sub-lethal amount of zinc phosphide bait can result in bait shyness. Therefore, do not use zinc phosphide more than once per 6-month period.

In some cases, the use of second generation anticoagulants (for example, brodifacoum, bromadiolone) or other toxicants (cholecalciferol) may be permitted for woodrat control. Based on Section 2 of FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act), EPA ruled that it is legal, unless otherwise specifically prohibited, to use a pesticide against a target species not listed on the label if the label directions for a listed pest are followed. The site to be treated must be mentioned on the label and there must be reason to believe the application will be effective. For example, the use of cholecalciferol to control woodrats in or around buildings could be permissible because the label lists Norway or roof rats and specifies in or around buildings. Not all states accept the EPA ruling. Check with the appropriate pesticide enforcement agency prior to pursuing this course of action.

Trapping

The majority of woodrat problems in structures can be dealt with by using one or several traps. Woodrats show little fear of new objects in their environment and are easily trapped. The standard rat snap trap is quite effective for woodrats. Trap bait should be wedged into or tied to the treadle. Good baits include nut meats, bacon rind, peanut butter and oatmeal, prunes, raisins and other dried fruit, and biscuits.

Live catch traps, using the same baits as above, can be used for woodrats. Release of trapped animals is not recommended and may be against local fish and game regulations. Also, many studies have shown that animals released into new areas often die from exposure, predation, or competition with resident animals.

Burrow-entrance traps such as the No. 110 Conibear® trap may also be useful for woodrat control. The trap is placed in nest openings or other restricted travelways and is triggered when the woodrat passes through the trap opening. When traps are set in this manner, baiting is not necessary, but care must be taken to avoid nontarget animals.

Glue boards are also effective for trapping woodrats. These work on the same principle as flypaper; when a rat attempts to cross a glue board, it gets stuck. Glue boards tend to lose their effectiveness in dusty areas, and temperature extremes may affect the tackiness of the adhesive. In many cases, woodrats trapped on glue boards will not die immediately. If they don't, they can be euthanized by placing the board in a plastic bag and adding carbon dioxide gas.

Remember, all traps and glue boards should be placed so that children, pets, and other nontarget animals do not have access to them.

Other Methods

Destroying woodrat nests has been suggested as a method of control. When a nest is destroyed, the animals may run for cover, thus exposing them to predation by humans or dogs. This method of control is time-consuming and probably of limited value. Once the woodrats in an area are controlled, however, destroying their nests may reduce invasion by other woodrats.

Economics of Damage and Control

Nationally, woodrats are a minor pest. They only occasionally become numerous enough to cause significant agricultural damage. In most cases, woodrats are a nuisance around vacation homes, cabins, and other outbuildings. Their stick nests can be extensive and their physical presence and droppings are often objectionable. Woodrats can carry diseases and ectoparasites. Therefore, close association with humans is undesirable. In most nuisance situations, control can be accomplished by the resident or homeowner.

Acknowledgments

Figure 1 from Schwartz and Schwartz (1981).

Figures 2, 3, 4, and 5 adapted from Burt and Grossenheider (1976) by David Thornhill.

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Editors
Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Rex O. Baker
Professor and Research Project Leader
Horticulture/Plant & Soil Science
California State Polytechnic University
Pomona, California 91768

Gerald R. Bodman
Extension Agricultural Engineer — Livestock Systems
Department of Biological Systems Engineering
University of Nebraska
Lincoln, Nebraska 68583

Robert M. Timm
Superintendent and Extension Wildlife Specialist
Hopland Research and Extension Center
University of California
Hopland, California 95449

RODENT-PROOF CONSTRUCTION AND EXCLUSION METHODS

Importance of Rodent-Proof Construction

Rats and mice cause serious damage to all kinds of structures if they are allowed access to them. Damage by rodents has been documented in homes, apartments, hotels, office complexes, retail businesses, manufacturing facilities, food processing and warehouse facilities, public utility operations (especially power and electronic media operations), farm and feed storage buildings, and other structures.

In urban settings, rodents most often cause damage to older, inner-city buildings and utilities in poor repair. New housing developments may experience commensal rodent problems, but problems are more noticeable in neighborhoods 10 to 12 years of age or older. Ornamental plantings, accumulation of refuse, woodpiles, and other such sources of harborage and food are more quickly invaded and occupied by rodents when adjacent to an established rodent habitat.

Many types of land, air, and water transportation systems and their infrastructure also face serious rodent infestation problems. Infestations are of particular concern in the transportation of foodstuffs, feed, and other agricultural products. Commensal rodents consume and contaminate human and livestock feed. One rat can eat about 1/2 pound (227 g) of feed per week, and will contaminate and waste perhaps 10 times that amount.

Rodents destroy insulation, electrical wiring, plumbing, and other structural components of buildings (Fig. 1). Insu-

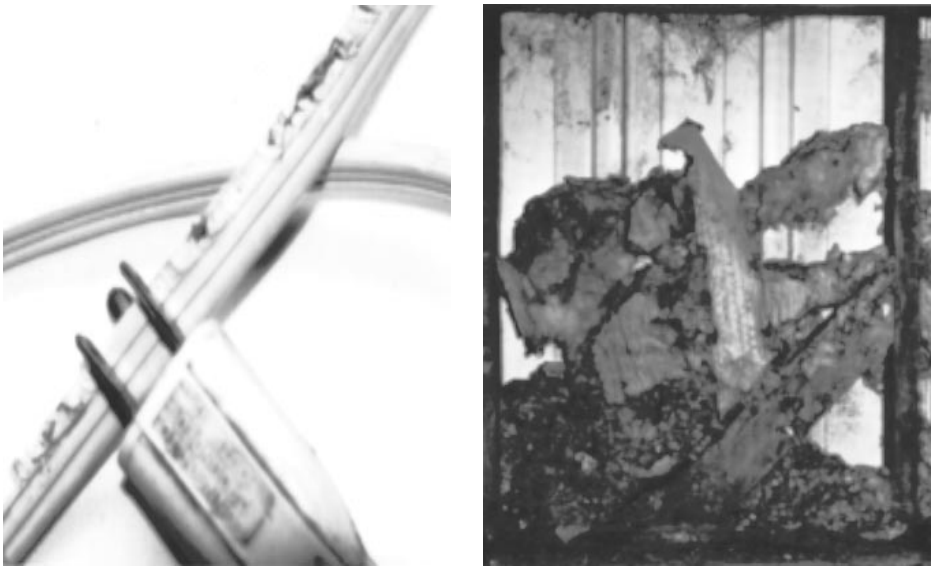
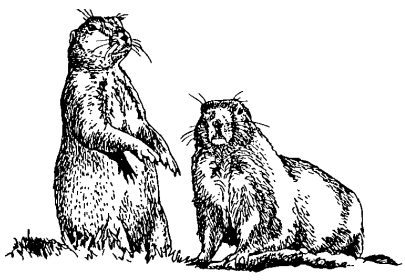


Fig. 1. (a) Electrical cord of a freezer in a retail market, severely damaged by house mice; (b) fiberglass batt insulation within walls of a hog finishing house near Lincoln, Nebraska, was destroyed by house mice in less than 3 years.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

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lation damage alone may amount to a loss of several thousand dollars in only a few years. Energy loss from damaged buildings results in added annual costs. Rodent-induced fires from damaged electrical wiring or nest building in electrical panels cause loss of property and threaten human safety. Rodents also serve as vectors or reservoirs of a variety of diseases, such as salmonellosis, leptospirosis, and murine typhus, that are transmittable to humans. Additionally, they may be sources of swine dysentery, brucellosis, sarcoptic mange, and tuberculosis, all of which affect livestock or pets.

The most effective means of limiting rodent damage is rodent-proof construction. New buildings should be designed and built to prevent rodent entry. Rodent-proofing is a good investment. Designing and constructing a rodent-proof building is less expensive than adding rodent-proofing later. Nevertheless, poor maintenance or management practices, such as leaving entry doors and unscreened windows open, will make the best-constructed building susceptible to rodent entry. Techniques discussed here apply both to new construction and to the modification of existing structures.

Junctures where utilities (pipes, cables) enter structures require special consideration in preventing rodent entry. Some earthquake design criteria require open spaces in important joints and other support areas, to allow for limited movement of tall structures. These present a real challenge in the design of rodent-proof construction.

Physical Abilities of Rats and Mice

To prevent rodent entry, their capabilities must be understood. For example, both rats and mice can:
- run along or climb electrical wires, pipes, fences, poles, ropes, cables, vines, shrubs, and trees to gain entry to a building (Fig. 2);
- climb almost any rough vertical surface, such as wood, brick, concrete, weathered sheet metal, and many plastic products;

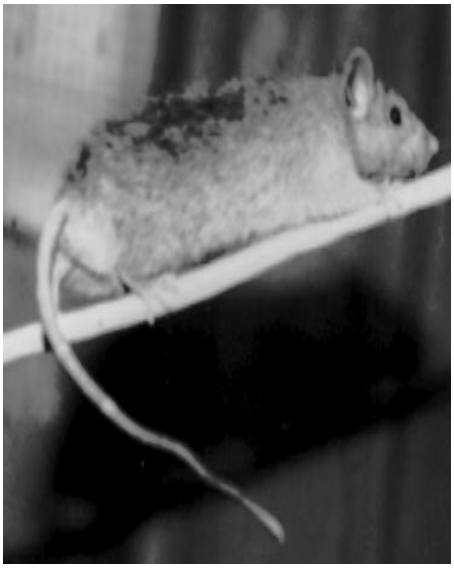


Fig. 2. Rat traveling along an electric wire.

- crawl horizontally along or through pipes, augers, conveyors, conduit, and underground utility and communications lines;
- gnaw through a wide variety of materials, including lead and aluminum sheeting, window screens, wood, rubber, vinyl, fiberglass, plastic, and low-quality concrete or concrete block.

Rats can:
- crawl through or under any opening higher or wider than 1/2 inch (1.3 cm) (Fig 3);
- climb the outside of vertical pipes and conduits up to 3 inches (7.6 cm) in diameter; climb the outside of larger pipes attached to buildings by bracing themselves between the wall and the pipe; climb the inside of vertical pipes, wall voids, or earthquake safety seams and joints between 1 1/2 and 4 inches (3.8 and 10.2 cm) in diameter;
- jump from a flat surface up to 36 inches (91 cm) vertically and as far as 48 inches horizontally;
- drop 50 feet (15 m) without being seriously injured;
- burrow straight down into the ground for at least 36 inches (91 cm);
- reach as high or wide as 13 inches (33 cm);
- swim as far as 1/2 mile (800 m) in open water, dive through water traps in plumbing, and travel in sewer lines against a substantial water current. In areas where high rat populations exist, it is common for both roof rats and Norway rats to enter buildings through toilets and uncovered drains.

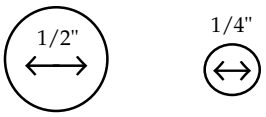


Fig. 3. Rats can gain entry through holes larger than 1/2 inch (1.3 cm); mice can use holes larger than 1/4 inch (0.6 cm).

House mice can:
- enter openings larger than 1/4 inch (0.6 cm);
- jump as high as 18 inches (46 cm) from a floor onto an elevated surface;
- travel considerable distances crawling upside-down along screen wire;
- survive and reproduce at a temperature of 24°F (-4°C) if adequate food and nesting material are available.

Survey for Entry Points

When inspecting sites for potential rodent entry points, look for rub marks, droppings, tracks, gnawing, or other rodent signs. Special attention should be paid to areas discussed under Common Rodent Entry Points (below). Keep in mind the physical abilities and behavior of the particular rodents, especially their tendency to seek shelter behind, under, or in appliances, sinks cabinets, drawers, stored goods, wall voids, false ceilings, and other undisturbed areas.

To conduct a thorough survey, inspectors will need an inspection form and paper for noting and illustrating items needing attention; a good flashlight; a mirror (to see under and behind objects); and screwdrivers and other small hand tools to remove interior and exterior vent grills, appliance base plates, and service doors to attics, crawl spaces, and utility cabinets. A tape measure is usually necessary when preparing a plan and estimating materials needed for repair. A small dustpan, broom, and some lime, flour, or similar powdered material are useful in preparing an area for a follow-up

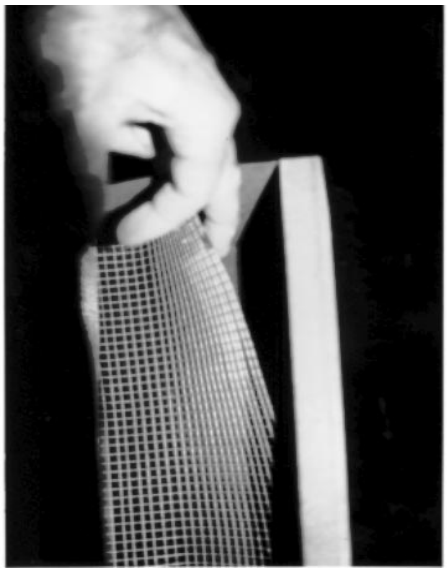


Fig. 4a. Low-profile wall vent with poorly attached hardware cloth, allowing for easy rodent entry.

Fig. 4b. Gap (3/4 x 26 inch) between wall covering and framing at roof joint, allowing rats and mice easy access.

Fig. 4c. Large hole gnawed by Norway rats in weather strip on the base of a warehouse door.

observation of fresh tracks. A camera can be of great value, especially when trying to design a project after leaving the site, or when seeking assistance from someone unfamiliar with the site. A simple item to use when measuring gaps under doors or around pipes, screens, or vents is a common wooden pencil or ball-point pen (usually 3/16 to 3/8 inch [0.5 to 1.0 cm] in diameter) — large enough for mouse entry.

Common Rodent Entry Points

Many structures have inherently similar rodent entry areas due to similarity in design (particularly entry and service areas), utility sources, and building equipment. For the sake of simplicity, we have attempted to group similar structures and settings.

Commercial Office Buildings, Hotels, Hospitals, and Retail Stores. Commercial buildings are constructed from types of materials and design methods that vary greatly in the degree of susceptibility to rodent infestation (for example, metal and concrete versus wood). Most structures eventually become less rodent-proof due to deterioration, alteration, or repair. Heating, air conditioning, plumbing, electrical service, and fire sprinklers provide some of the most commonly encountered rodent entry points. Neoprene seals, spray-in-place foam, and similar products commonly used to close openings are not rodent-proof.

Even in new buildings, utility pipes, electrical conduit (often at meters or circuit breaker panels), water and gas lines, and communication cables generally have large openings that permit entry of mice and rats. Once rodents have entered walls, they generally have ready access to much of a building via holes for utility pipes and wires in the framing, and via overhead suspended ceilings or other types of construction adjacent to utility enclosures. Specific problem areas include poorly sealed heating and air conditioning ducts; roof and wall vents installed without strong, well-attached hardware cloth screening (Fig. 4a); roof and wall joints and edges without properly installed metal flashing (Fig. 4b); and doors hung unevenly or too high, or lined with unprotected soft rubber weather stripping (Fig. 4c). Refuse and food handling areas are likely to have the greatest rodent pressure. In older buildings, cracks in concrete slabs, brick and concrete block walls, or worn or damaged drain covers allow rodent entry. Air and elevator shafts and laundry chutes also merit close inspection.

Food Handling Facilities and Warehouses. Businesses in which food is stored or handled are especially prone to rodent invasion. Good sanitation practices are essential. Keeping food well-sealed is very important and more difficult than might initially appear. Scraps of food can often be found in floor drains, under food preparation equipment and stored products, and around refuse and entry areas. Outside doors are often left ajar or fit poorly due to heavy use, physical damage, or improper installation.

Space under equipment (mixers, stoves, counters, or refrigerators) should allow easy cleaning and inspection, or be closed off completely with rodent-proof materials (Fig. 5). Mice and rats are sometimes found using freezer and refrigerator compressor areas for harborage and water (from condensation on cold coils). Mice are often found in the insulated walls of large coolers. Look closely at corners and edges of metal, or other material covering the insulation, for rodent openings. Drains should have adequate screens or grates to prevent rodent entry.

Food disposal, refuse, and damaged goods areas are often located close to food handling or storage areas and are not sealed from rodents. Areas near loading docks should be closely

Fig. 5. Area under food preparation equipment is raised above a smooth stainless steel floor, allowing for easy cleaning of food spills and open to prevent harborage.

Fig. 6. Poorly installed light-gauge roof vent, allowing easy access of rodents between roofing and base of vent. Gaps were large enough to allow rats and pigeons to enter.

inspected for cracks, broken screens, damaged doors, and uneven floors near doorways. Interior loading docks served by rail cars are difficult to close due to the tracks, but rubber door guards made to fit the tracks are available and will deter rodent entry.

Rodent-infested goods in food warehouses commonly include cereals, flour, and baking mixes; waxed carton drinks; dry pet foods; dried fruits and nuts; fresh produce; paper goods; charcoal briquets, and damaged goods. Products in these categories should be kept in open, easily inspected areas, not in dark corners. Regular and routine removal of such nonsalable or nonusable products should be standard practice to enhance cleanliness and safety and to reduce harborage.

Apartments and Houses. Utility entry points include underground electrical and communication trunk lines, and exhaust vents for clothes dryers. Power lines have always been a favorite route of travel for commensal rodents, especially roof rats. Check all roof joints for tightness and presence of flashing, if rats and mice have access to the roof via wire, pipes, plants, or rough-textured walls. Also check roof and sewer vents for adequate screening and sealing, including presence of tight roof jacks (Fig. 6). Chimneys should be checked for properly installed flashing or for missing mortar.

Rats occasionally enter buildings through toilet traps in inner-city areas with rat-infested sewer systems. In such cases, tracks and water may be found on the rim of toilet bowls. Both roof and Norway rats have been known to enter structures via the sewage system. This route usually occurs in older (20 years or more) established areas with poorly maintained sewer systems. Mice often enter under entry doors, through holes beside water pipes and electrical conduit, and through the cold air return ducts on forced air furnaces, especially those located in outside cabinets or garages, and underneath mobile homes. Mice and rats often find easy access to garage areas through open doors or under and beside poor-fitting garage doors. Once in the garage, they may gain entry into the main structure along electrical lines, pipes, poorly sealed fire wall sheathing, or around furnace ducts, hot water heaters, or laundry drains.

If rodents are able to reach the attic, they may travel from room to room or unit to unit through openings for pipes, ducts, and wiring. Attics provide excellent harborage in winter, spring, and fall, but are often too hot during summer. Common attics, basements, or raised foundations in condominiums and apartments are a frequent source of rodent infestation.

Another source of entry to residences, and a source of harborage for rats and mice, are fireplaces—especially the newer preconstructed zero clearance sheet metal units that eliminate the need for concrete mortar and brick. A hollow space is left in the siding and the fireplace support framing between the outside wall and the fireplace. Rats and mice can enter this area from the outside via the roof joint, between the siding and decorative wood corner trim, around gas pipes, or outside wood storage doors.

Once a rodent gets into the attic, inside entry to the fireplace void is often easy because of poorly fitted sheeting or metal collars. Entry to the inside of the fireplace is made from the damper area or cool air and warm air returns on units that provide for air circulation around the firebox. When the fireplace is in use, the heat will prevent rodent entry. If the outside cannot be sealed, glass doors that seal the burn area are recommended to prevent rodent entry throughout the year. Cracked and missing mortar, or poorly fitted siding or plaster, may allow entry through brick or rock fireplaces.

Tile or shake shingle roofs allow rodent entry if the roof is not solidly sheeted with plywood or similar material and the tile is not properly fitted and grouted. Vents without tightly fitted double roof jacks also facilitate access to rodents.

Gaps or flaws in foundations and slabs, or where the wall framing meets the foundation or slab floor, may provide large enough openings for rodent entry. Older buildings commonly have cracked foundations, cracked plaster or mortar, warped siding, or broken and torn vent screens. Wood or masonite siding is especially vulnerable to warping and cracking near corners and around the base of the building. Old, unused holes where utilities formerly entered the structure are also

common, especially in raised foundation and basement homes. Window screens are often left off or fit poorly in older, low-cost apartments and homes, allowing rodent entry from exterior utility lines and pipes running along exterior walls. Runways going to window ledges are often observed on stucco and brick walls and in ornamental plantings next to buildings.

Manufacturing Plants and Farm Buildings. Overhead or underground pipes, conveyor belts, and augers commonly found in farm buildings and factories are often used as entry points and routes into and between buildings. Such equipment, particularly if abandoned, may provide harborage as well as food. Rodent-proofing these areas is not easy if the equipment is still in use.

Utility entry points must be constantly monitored for excess openings caused by equipment repair, installation, or modification. Outside walls and doors must also be monitored for damage from equipment or livestock and for damage or wear from heavy use. If work patterns require doors to be open during hours of darkness, when rodent entry is most likely, rodent barriers may be needed, such as a solid fence or wall or a metal wing wall between the foundation and adjacent loading dock areas (Fig. 7).

Buildings constructed with ribbed or corrugated metal siding allow rodent

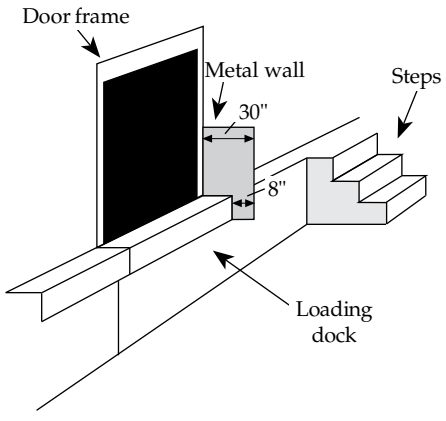


Fig. 7. Rodent barrier or guard used between steps, foundation, or other sources of rodent entry and the loading dock doors when doors must be left open at night.

Fig. 8. Large gap between roll-up warehouse door frame and wall, allowing for easy rodent access.

entry if the bottoms of the siding panels do not rest flat on a solid surface or they are not otherwise closed off. Sections of prefabricated buildings should be assembled tightly, and gaps at joints should be covered with metal flashing. Often, however, they are left open, especially at corners and at the foundation/slab interface.

Roll-up or overhead doors often provide easy entry for rodents, birds, and bats. With the door closed, check for gaps along the sides, bottom, and top of the door (Fig. 8). A gap at the top is common. Rats and mice can easily climb up the space between the door and the inner wall or track to the top, where they gain entry and climb down the inside of the track. Gaps between the track and the wall are also common, especially if the track has been installed on brick walls. Door bottoms may be bent or damaged, leaving gaps along the floor. Uneven floors due to frost heaves may leave gaps when the door is closed.

Screens on windows, crawl spaces, and vents are often damaged in farm and industrial buildings. Check these carefully for needed repair or replacement.

One of the greatest challenges in farm buildings is preventing feed and seed from being a food source for rodents. Good sanitation practices are very important. Clean up spilled feed, and store feed and seed in rodent-proof buildings and containers. Keep sacked materials off the floor when possible. This facilitates for inspection and reduces harborage.

Excluding rodents from livestock and poultry operations is another challenge due to livestock and manure management and various animal husbandry practices. Nevertheless, rodent-proofing is important and can be accomplished. Many of the entry points already identified for other types of structures apply to farm buildings. Additional problem areas include insulated walls used for harborage, feed bins, and portable feed bunks. These are but a few of the challenges discussed in more depth under Exclusion Methods (below).

Exclusion Methods: Existing Structures and Equipment

Holes and Openings. By gnawing, rats can gain entry through any opening greater than 1/2 inch (1.3 cm) across, and mice through any opening larger than 1/4 inch (0.6 cm). The paired front (incisor) teeth of rats and mice curve slightly inward. This inward curve makes it difficult for them to gnaw into a flat, hard surface. When given a rough surface or an edge to bite into, however, they can quickly gnaw into most materials. To prevent rodent entry, seal all such holes with durable materials. Steel wool, copper gauze (Stuf-it® brand) or screen wire packed tightly into openings is a good temporary plug. For long-term or permanent repair, mix a quick-drying patching plaster or anchoring such as Fixall® into a wad of Stuf-it® before pushing the material into the hole, and smooth over the outside (Fig. 9). If steel wool is used, rust stains are likely to result. Holes 3 inches (8 cm) or more in diameter should be covered or backed with 1/4-inch (0.6-cm) woven/welded hardware cloth prior to filling with a good patching compound (see recommendations under Foundations and

Fig. 9. Patching small holes with copper gauze and a fast-drying patching compound (left), and 1/4-inch hardware cloth for larger holes (right).

Fig. 10. Frequently used patching materials on 1/4-inch woven hardware cloth backing. Fomofill®, Pour Stone®, Fix-all®, and Custom Plug® are shown as examples of the many materials available.

Table 1. Recommended materials for rodent-proofing.

Concrete: Minimum thickness of 2 inches (5.1 cm) if reinforced, or 3 3/4 inches (9.5 cm) if not reinforced.

Galvanized sheet metal: 24 gauge or heavier for wall or pipe barriers; 22 gauge or heavier for kick plates or door edging. Perforated or expanded sheet metal grills should be 14 gauge.

Brick: 3 3/4 inches (9.5 cm) thick with joints filled with mortar.

Hardware cloth (wire mesh): Woven, 19-gauge, 1/2- x 1/2-inch (1.3- x 1.3-cm) mesh to exclude rats; 24-gauge, 1/4- x 1/4-inch (0.6- x 0.6-cm) mesh to exclude mice.

Aluminum: 22 gauge for frames and flashing; 18 gauge for kick plates and guards.

Floors). Another backing material available is Strong Patch™ (D. P. Wagner Mfg. Inc.), a 6 x 6-inch (15 x 15-cm) sheet metal patch to cover holes up to 5 x 5 inches (11 x 11 cm). It has a self-adhesive backing and a mesh on the surface for better adhesion of the patching compound or other texture.

To close larger openings or protect other areas subject to gnawing, use materials such as those listed in Table 1. Hardware cloth, if not woven, breaks easily. The woven/welded hardware cloth maintains its shape when cut to fit around pipes or other objects. Hardware cloth used to cover gaps and holes can be filled with foam caulk, Fix-all®, Quick-Fix®, or other fast-drying interior patching compounds. When used on the exterior, concrete mortar, plaster, or Concrete Patch® can be used to provide longer-term rodent-proofing (Fig. 10). These are just a few of the many products available.

Close openings around augers, pipes, and electric cables where they enter structures with Portland cement mortar, Concrete Patch®, masonry, or metal collars (Fig. 11). Even a small unprotected opening can be an invitation to rodents.

The ribs and corrugations in metal siding can be blocked with metal or mortar. Rubber or vinyl weather stops are quickly gnawed through. Design or modify buildings with metal siding by butting siding panels or sheets against solid materials (metal flashing or concrete) so the openings are not present (Fig. 12). **Caution:** letting metal siding rest directly against concrete can lead to accelerated rusting and corrosion. The siding should be installed so that openings are no greater than 1/8 inch (0.3 cm) wide. If the siding is installed with the ribs horizontal, the ends must still be sealed or the bottom of the decorative corner trim flashed and closed.

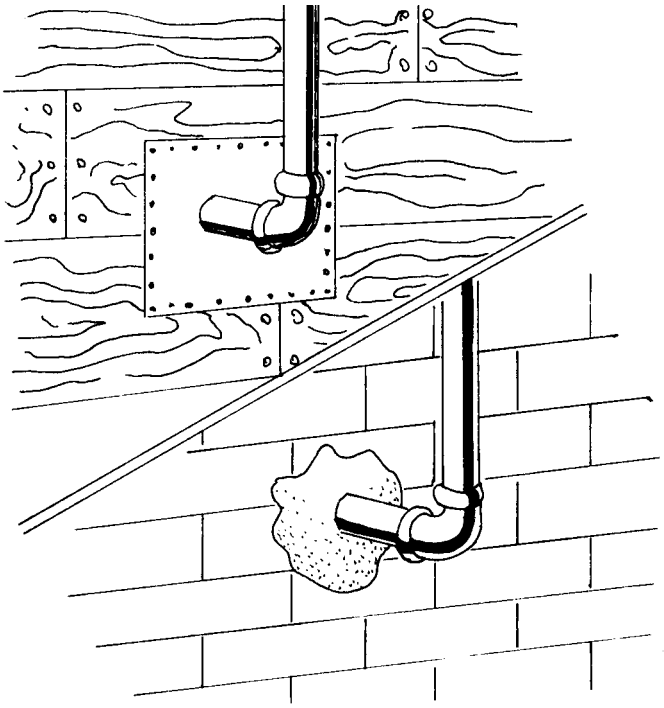


Fig. 11. Seal gaps or holes with rodent-proof materials where pipes, wires, or other similar objects enter buildings.

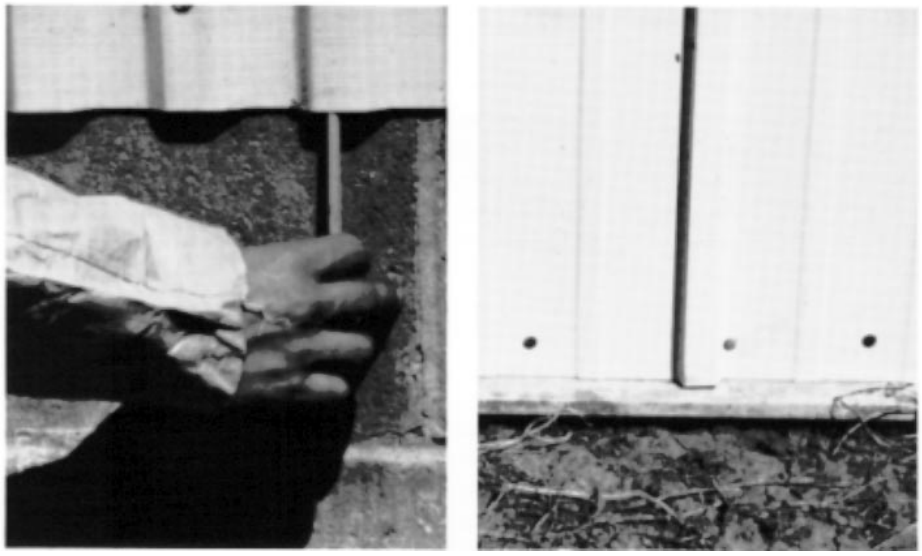


Fig. 12. Metal siding may provide entry points for mice and rats where panel ends are left open (left). Properly installed metal siding rests on the concrete floor or has metal flashing or angle iron to block entry (right).

Vents and Windows. Use only metal window screening materials where windows or doors are accessible to rodents. Avoid unnecessary ledges outside windows. When necessary, screen ventilation openings and windows with woven/welded galvanized hardware cloth. Such screening is critical in commercial and farm buildings and where high rodent pressures in residential areas are found. For large openings or where the screen may be subject to abuse, add crossbars to support the hardware cloth. If the opening is an access route, install the screen on a hinged frame.

All vents and duct openings for heating and air conditioning should be screened or raised and/or guarded with an excluder device to prevent rodent entry. Residential cold air return grills can easily be mouse-proofed by placing 1/4-inch (0.6-cm) hardware cloth behind the grill where it is not unsightly. In some applications, power vents can be covered with hinged metal plates (louvered) that open with air flow and close when fans are off. These louvers are only effective if they fit tightly and the sides are recessed to prevent rodents from pushing through them. **Caution:** Hardware cloth less than 1/2 x 1/2 inch (1.3 x 1.3 cm) significantly reduces air flow. In buildings where ventilation is already marginally adequate or inadequate, such further restrictions may be unacceptable. In some locations, small mesh screens can become clogged with dust or freeze over. In such situations, the use of 1/2 x 1/2-inch (1.3 x 1.3-cm) hardware cloth is a reasonable compromise between ventilation requirements and rodent control.

Exterior Doors. Doors should fit tightly, the distance between the bottom of the door and the threshold not exceeding 1/4 inch (0.6 cm). In some instances, it is possible to build up the threshold rather than modify the door. Metal thresholds can be fastened to floors. Steel pipes embedded in a concrete floor make good rodent-proof thresholds and allow doors to swing free when open. Pipe thresholds are especially useful where doorways are used by wheeled pallet jacks, heavy equipment, or livestock. Install flashing or a metal channel on the lower edge of doors, particularly softwood doors (Fig. 13); a plastic door boot has been successfully used where the door receives low use and the edges are not easily accessible to rodent gnawing. Properly applied flashing extends to within 1/8 inch (0.3 cm) of the edge of the door at the sides and bottom. Close the gap at the top or sides of roll-up doors with conveyor belt material shaped to fit into the side channel frames and mounted on the top door jamb. Bent bottom rails on doors should be straightened. Concrete damage due to inadequate reinforcement or poor placement practices should be repaired or the concrete replaced. A metal or pipe threshold is sometimes preferable or required.

Mechanical door-closing devices save time and help overcome human negligence. Equip doorways used for ventilation with rodent-proof screen doors, or if the door surface is too slick for rodents to climb, modify the existing door so the upper half can be left open for ventilation. Always use a heavy kick plate and solid frame on screen doors in commercial and agricultural

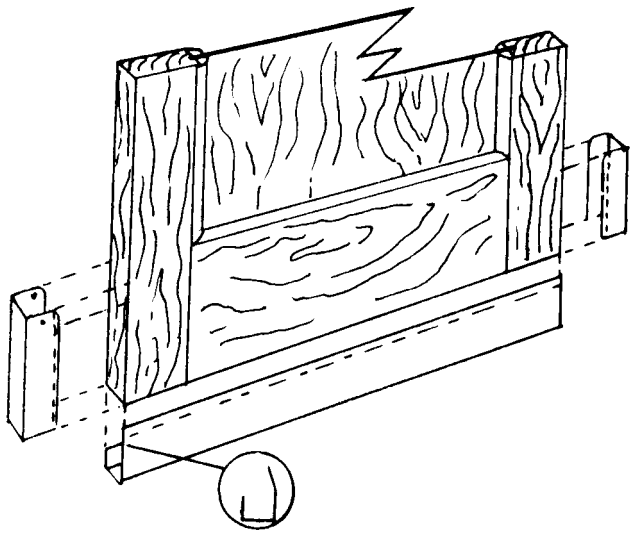


Fig. 13. Metal flashing or metal channel prevents rodent gnawing at bottom edges of a door.

buildings. Light-framed screen doors easily get bent out of shape, allowing rodent entry.

Foundations and Floors. Gaps or flaws along building exteriors where the wall framing or siding meets the foundation provide easy entry for rodents. Such openings can be prevented by well-formed and finished concrete work and installation of tight wall framing and siding, or installing metal screed-type flashing between the siding and the foundation. Use of rodent-proof exterior surface materials such as concrete, plaster, or metal sheeting is also effective if properly installed so that all ribs or corrugations are closed.

Rodents can gain entry into buildings with piers or shallow foundation walls by burrowing beneath the floor or foundation. To prevent rat entry by this route, extend foundation walls below ground at least 36 inches (91 cm). This also reduces damage from frost. A horizontal footing extension also may be added to deflect burrowing rodents away from the foundation (Fig. 14). Avoid the use of slab-on-grade construction techniques for agricultural buildings or bulk bin pads. The possible savings in initial construction may be quickly offset by the costs of rodent damage and control measures.

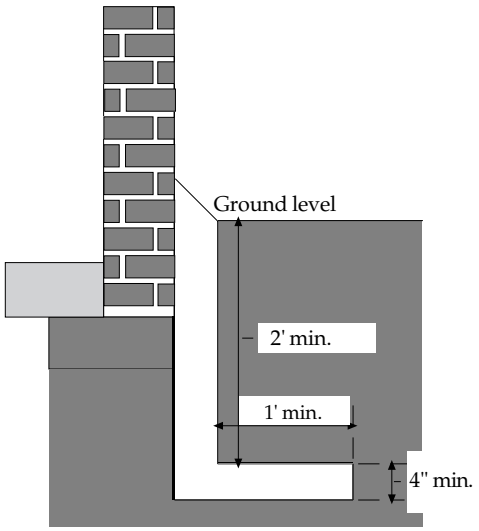
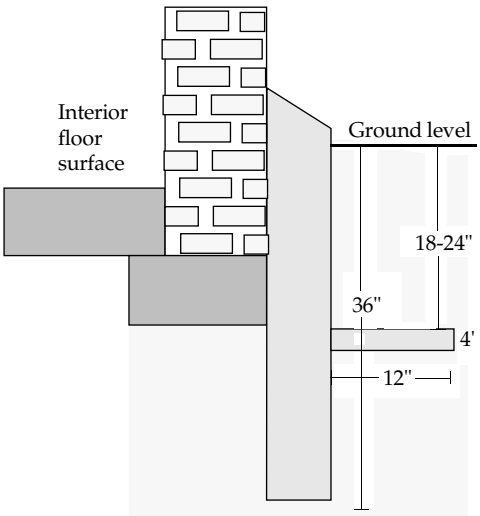


Fig. 14. A 1-foot horizontal footing extension to deflect burrowing rodents.



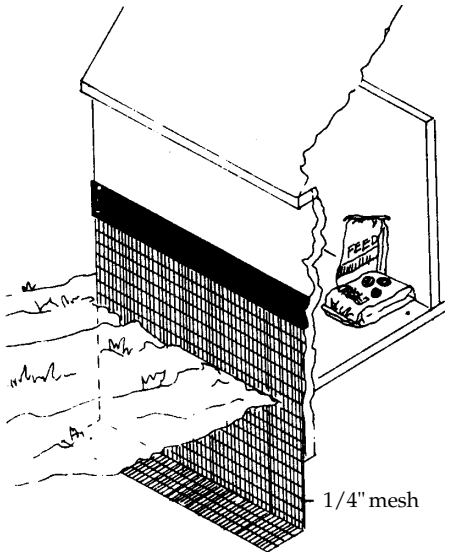


Fig. 15. *Left:* A curtain wall made of concrete will prevent rats from burrowing under foundations to gain entry to buildings. Curtain walls can be installed on existing buildings. A horizontal footing extension often deflects burrowing rodents away from structures. *Right:* Feed sheds, corn cribs, and other existing wooden structures can be rodent-proofed by installing hardware cloth topped by a band of sheet metal. The hardware cloth can also serve as a curtain wall to prevent rodent burrowing.

Rats exert more effort to enter buildings where feed is available. They frequently seek shelter under concrete floors and slabs, where they burrow to find protection. Ideally, install floors, slabs, and sidewalks with deep footings, or with curtain walls of concrete or 1/4-inch (0.6-cm) mesh wire (Fig. 15). The choice between concrete and wire mesh depends on the expected life of the structure. Though wire mesh costs considerably less than concrete, its usefulness generally lasts only 5 to 10 years.

Repair cracks in foundations and floors with concrete or masonry grout. There are numerous quick-setting types of products, such as Fix-all® or Quick-Fix®, which are for interior use, and Concrete Patch®, Rockite®, or Pour Stone® for interior or exterior use (previously illustrated in figure 10). The four last-mentioned products are specifically designed for repairs and have quick setting, good adhesion, and nonshrinking properties which make them ideal for exclusion work. Each, however, is made for a specific application: Pour Stone® and Rockite® are designed to be easily poured into cracks in floors or into holes to anchor bolts or machinery, and set hard in 15 minutes. Concrete Patch® is a mortar-type material for repairing masonry surfaces and has a vinyl polymer to increase adhesion. It sets in 2 hours and is hard after 12 hours. Quick-Fix® is a durable patching plaster for inside use on plaster, drywall, or wood surfaces. Drying time may be within 30 minutes, depending on thickness. With all of these types of repairs, the use of reinforcement with hardware cloth is usually needed on vertical or overhead horizontal surfaces to add strength and provide the necessary backing. Rodents can claw and gnaw at concrete and Portland cement until it is fully cured, so the use of 1/2-inch (1.3-cm) hardware cloth laid in the top 1/4 inch (0.6 cm) of the repair area may be necessary if rats are currently using the repair area as an entry point. Otherwise, provide an effective temporary rodent-proof protective overlay until the concrete is fully cured. **Caution:** Metal products placed within 1 inch (2.5 cm) of a concrete surface will oxidize and corrode and may discolor the concrete.

If rats have gained access to crawl spaces under building floors, prevent them from getting into walls by using such modifications as illustrated in figure 16.

Maintaining a clean, 3-foot-wide (1-m) weed-free area around building foundations, concrete slabs, and footings often discourages rodents from burrowing as well as eliminates a food

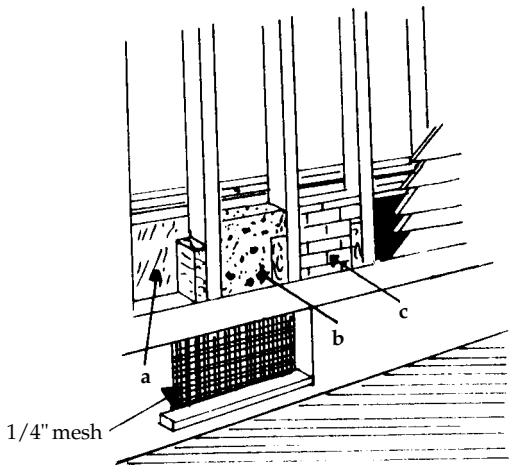


Fig. 16. Method of excluding rats from double walls. In old buildings, galvanized sheet metal (a) may be cut to fit and nailed into place between studs, joists, floor, and sill; in buildings under construction, noncombustible stops of good quality concrete (b) or bricks (c) are recommended.

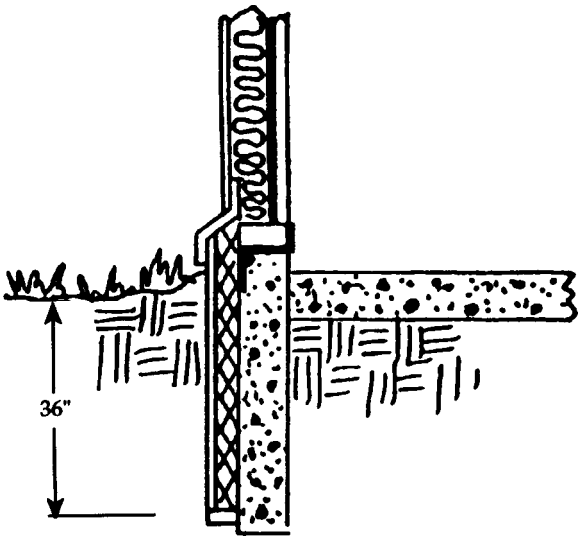


Fig. 17. Perimeter insulation placed on the outside of a foundation, curtain, or stem wall must be protected to prevent rodent damage. Protection is required along the top and to a depth of at least 36 inches below the soil surface.

source and attractive harborage. Where erosion of bare soil is likely, this buffer can be maintained by regular, close mowing of vegetation or by installing heavy gravel. To discourage burrowing, install a strip of 1-inch-diameter (2.5-cm) or larger gravel laid in a band at least 2 feet (60 cm) wide and 1/2 foot (15 cm) deep.

Interior Rodent-Proofing. When rats or mice are present in a building, attention must be given to interior as well as exterior rodent-proofing to remove all sources of shelter. A combination of actions is required in such instances, as no single effort is likely to yield the desired result.

Concrete floors are preferred to wooden floors. An attempt should be made to seal off rodents. Use traps to remove the rodents, or place poison bait packets through openings in the floor or wall and then seal the openings with galvanized metal or hardware cloth and patching plaster as previously discussed. Promptly treat new openings as they are found. In occupied buildings, always trap the rodents before sealing interior walls to avoid odors, stains, and an influx of insects that feed on decaying rodent carcasses.

Eliminate rodent hiding places beneath and behind equipment. Feeders in livestock facilities should have flat bottoms and be designed and installed so that rodents cannot find shelter beneath or behind them. Give special attention to storage rooms, closets, feed storage, or other areas where construction techniques may allow rodents access to walls, floor spaces, or attics. Stacks of wood and other stored items should be 18 inches (46 cm) above the floor and 18 to 24 inches (46 to 61 cm) away from walls to allow for proper cleaning and inspection. Warehouse stock should always be stacked off the floor on pallets and away from walls, and it should be rotated often to prevent development of infestations in undisturbed areas.

Rodents often gnaw into wall materials at corners or where joints in construction materials provide an edge. Poor construction techniques may allow rodents to gain access through materials that are otherwise considered rodent-proof.

Perimeter insulation is a necessary part of energy-efficient construction. Placing insulation on the exterior of foundation walls subjects it to mechanical damage as well as infestation and destruction by rodents. To prevent damage to perimeter insulation, use sandwich wall construction in which the insulation is placed within the concrete. Insulation placed on the outside of a foundation wall requires protective-covering material. Suitable materials include cement board, high density fiberglass-reinforced plastics, troweled-on coatings such as Block Bond®, or Surewall®. In such situations, metal flashing should be used to prevent the potential for entry routes for subterranean termites. Several companies now manufacture special coatings for exterior perimeter insulation. Examples include DuraWall™ and Securewall™.

Extend protective cover materials at least 36 inches (91 cm) below finished grade. If the protective layer ends less than 36 inches (91 cm) below grade, add a horizontal ledge that extends outward at least 1 foot (30 cm). All top edges and corners must also be protected with a close-fitting heavy-gauge metal flashing (Fig. 17).

Drains and Pipes. Both rats and mice use drainage pipes or sewage systems as routes to enter buildings. Equip floor drains with metal grates held firmly in place. Grate openings should not exceed 1/4 inch (0.6 cm). Maintain 1/2-inch (1.3-cm) hardware cloth over sewer roof vents in rat-infested areas. If the sewer system is known to be rat-infested, a "Rat Guard" one way flap valve may be

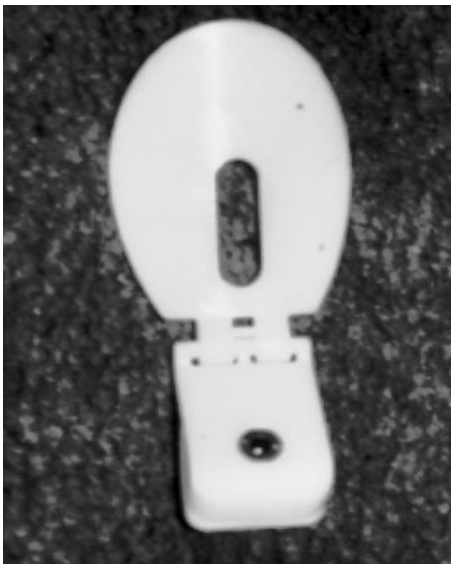


Fig. 18. "Rat Guard" one-way flap valve is available for placement in toilets where the sewer system is known to be rat-infested.

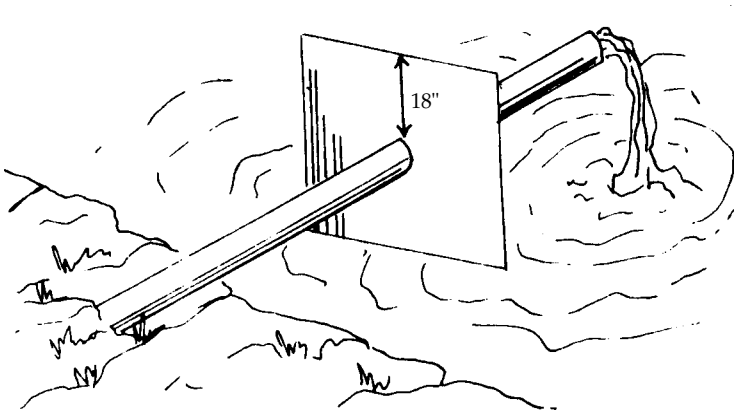


Fig. 19. Shield on manure discharge pipe to prevent access by rodents to open pipe.

placed in toilets (Fig. 18). Sewer laterals should be checked for openings that could allow rodent entry. Smoke-producing leak detectors are often used by agencies checking sewer lines for leaks or openings. If openings are detected, replace the pipe or wrap the pipe break with 1/4-inch (0.6-cm) hardware cloth and use concrete patching material to seal the area. Rain gutter downspouts are often used by rats to gain access to roofs. It may be possible to screen over openings at the base of downspouts with 1/2-inch (0.6-cm) hardware cloth or a grate, but this will require continued maintenance to remove accumulated debris, particularly where leaves and small sticks are washed from roofs into the gutter system. Flap valves have been used here too—swinging shut except when water is flowing. Openings to floor or driveway drains should have covers. Gutter and other drain covers must be kept clean of debris to prevent water backup.

Manure management systems in livestock facilities may be of a type that periodically drains manure or water from the building to a lagoon or other storage area. In such cases, a "floating" metal cover or check valve-style closure at the open end of the discharge pipe, with a hinge at its upper edge, can be effective. The hinge must operate easily so that the cover will open when water or manure flows out but will fall back into place when the flow stops in a manner similar to a tide gate used on drains in coastal areas. The potential for such covers to freeze shut, however, can be a drawback. A better method is to extend discharge pipes far enough over the bank or into the lagoon to prevent rodents from jumping or crawling into the open end. Install rodent shields to prevent rodents from gaining access (Fig. 19).

Always cap pump-out ports when under-building manure storages are not in use. Left open, they allow rodents easy entry.

Physical Barriers/Guards. To prevent rodents from climbing or traveling along a particular route, install guards made of sheet metal or similar materials (Table 1). Guards must be wide enough and positioned to keep rodents from reaching their outer margins by climbing or jumping. Dock areas may need guards to keep rodents from jumping or climbing from foundations, pipes, steps, or rough exterior wall surfaces, and from infesting trucks or rail cars transporting goods.

A sheet metal band attached to a wall will prevent rodents from climbing. Rodent guards should be at least 14 inches (36 cm) but preferably 18 inches (46 cm) wide (Fig. 20). Inside buildings, such guards can prevent rats and mice from climbing at corners. Used in combination with hardware cloth or other suitable material, they can make a building essentially rodent-proof. These modifications are essential on pumping plants, water treatment facilities, power stations, and communications facilities. They have also been used to make corn cribs, barns, and other older buildings in current use rat- and mouse-proof.

Fig. 20. Sheet metal band attached to outside walls to prevent rodent climbing. Band should be 14 to 18 inches wide and 30 inches above where a rodent can jump from.

Guards on walls should be at least 36 inches (91 cm) above ground or floor level. Flat guards have been used to prevent rodents from traveling along horizontal or vertical pipes or electric wires (Fig. 21). Cones or discs act as rodent guards on suspended cables, rain gutter downspouts, conduit, ropes, augers, or pipes (Fig. 22). With

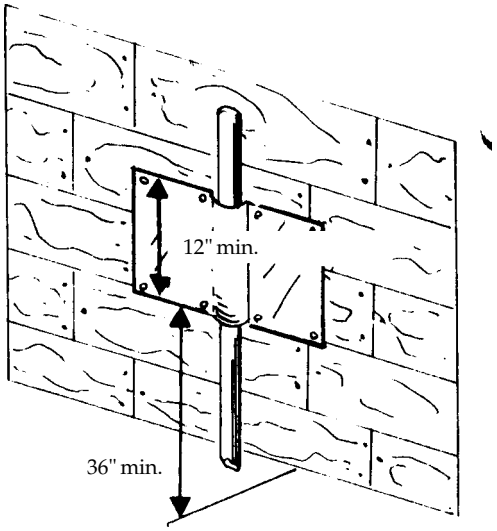


Fig. 21. Guards of various designs can prevent rodents from climbing along wires or pipes.

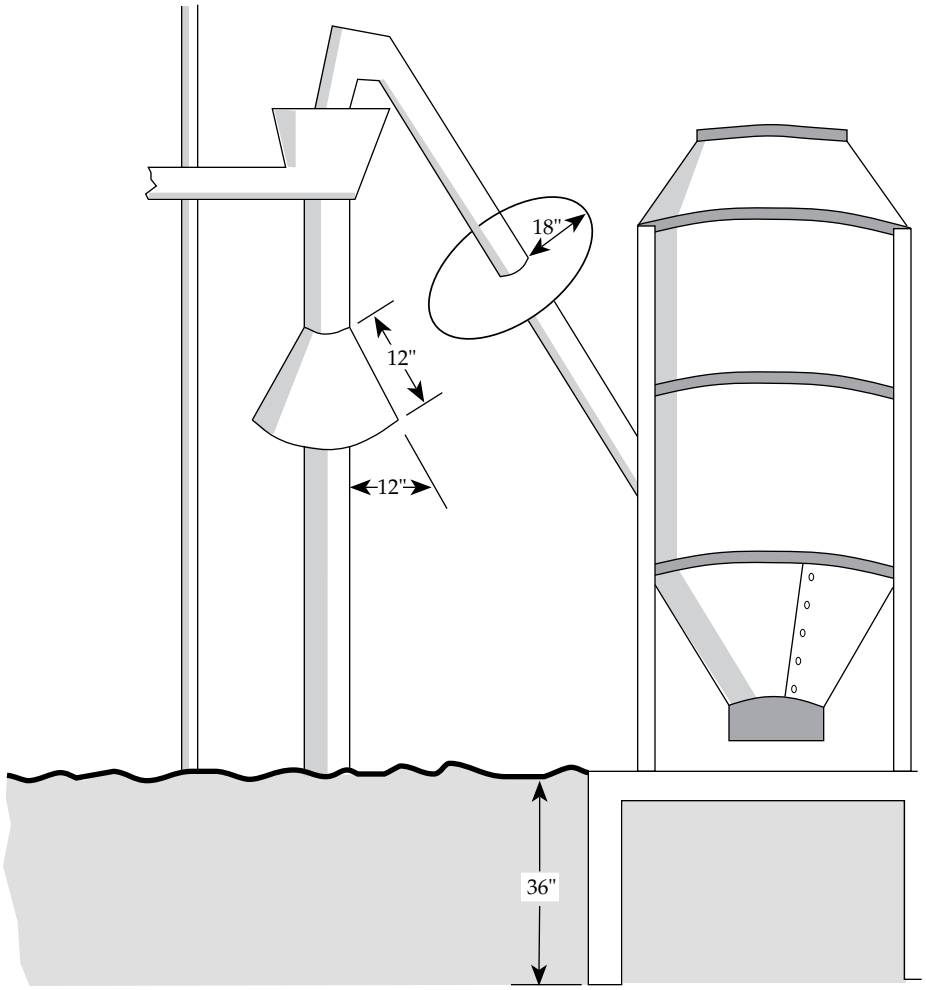


Fig. 22. Guards can be used to prevent rats from climbing augers, pipes, or wires leading to buildings. Footings or foundations for grain bins should extend into the ground to prevent rat burrowing.

some ingenuity, you can design rodent guards to fit any given situation. Free-hanging guards are easily damaged. Circular guards must extend out 18 inches (46 cm) around the line they guard. They are constructed of 24-gauge metal and anchored in place by one or more arms on the side opposite to that accessible to rats. Cone-shaped circular guards prevent rats from climbing vertical pipes, pilings, and trees. Shields or wire guards made of 1/4-inch (0.6-cm) wire mesh are useful in excluding rodents from the interior of conveyor belts, underground power and communications conduit, feed augers, fan housings, and similar openings.

Food Handling and Storage Areas. Even when all of the holes are plugged, rodents seem to find a way into food storage and handling areas. Sometimes rodents come in with supplies, or they run in through open doors or windows. Often, one or more openings remain undetected. These hidden holes are often below sinks, behind equipment, in false or suspended ceilings, and behind or under cupboards. Once in an environment having all the basic needs, rodents quickly establish viable populations. The solution is to eliminate harborage and exclude rodents from food and water sources inside the building.

All equipment such as large refrigerators, freezers, counters, dishwashers, and sanitizers should be raised and easily movable, enabling cleaning underneath and behind them. Insulated walls and closed areas should be tightly closed off to avoid use as harborage. Openings are commonly seen in new stainless-steel work counters in supports under the work surface, or in areas provided for drains. Drains should be easy to clean but should have rodent-proof covers.

Store food products in rodent-proof enclosures or on shelving at least 18 inches (46 cm), but preferably 30 inches (76 cm) or more, above the floor. Tubular supports (legs) for shelving should be a minimum of 4 inches (10 cm) in diameter to prevent rats from shinnying up from the floor.

Keep all damaged goods and returns, as well as refuse, in a separate rodent-proof room. Loading docks should be very tightly rodent-proofed and only open during daylight hours. All outside doors should be self-closing, have heavy kickplates, and be checked periodically for excessive gaps. In warehouses and storage situations, centralize highly susceptible foodstuffs into areas that can be securely rodent-proofed and closely monitored. These areas should also have rodent bait stations and multiple-capture mouse traps permanently installed around the perimeter.

Livestock Feed Bunks and Bins. Rats typically burrow and nest under feed bunks that are placed directly on the ground or near ground level. Properly designed concrete bunks that sit tightly on a concrete base eliminate rodent habitat. Though cattle traffic may discourage burrowing under the concrete slab, a foundation may be needed to prevent burrowing around the sides of the slab that do not receive heavy cattle use. Concrete slabs on which feed bins are placed should have foundations extending 36 inches (91 cm) into the soil at the outer edge to prevent rats from burrowing under the slab. Installing heavy gravel and maintaining a clean, weed-free zone around the perimeter of the slab will also discourage rat burrowing and permit easier detection of rat activity.

Feed and Refuse Storage. Livestock or pet feed and edible refuse attract rodents and are a common food source. Always store these materials in metal containers with tight-fitting lids. Food is often available to rodents around homes, kennels, and poultry and livestock feed storage areas because feed is kept in plastic or wood storage bins or hoppers. These storage containers are frequently open at the top, or may be gnawed through the sides. Check nonmetal hoppers frequently for holes and, when necessary, repair with sheet metal. Avoid the use of self-feeders for pets. Feed pets only as much as they will consume at one time and only during daylight hours.

Proper storage and disposal of household garbage and dead animals is a very important part of rat control. Bulk dumpsters are often left with the tops open, or the tops are badly bent, allowing rodent entry. Constant vigilance and calls to the refuse company should correct these situations. Seal bulk trash compactors from rodents. Spilled refuse and juices from crushed contents often create rodent problems under and behind compactors and bulk dumpsters. Clean these areas often and install rodent screening in container drains.

Rodent-Proof Building Design Considerations

The degree of a structure's susceptibility to rodent infestation depends on several considerations that the architect, engineer, builder, and end-user should keep foremost in mind prior to and during construction. All structures, but particularly those intended for human occupancy, should be built to be as rodent-proof as possible.

One consideration is the current and historical level of rodent problems in the general area of the construction site. A project that is in an inner-city redevelopment area with a known history of rodent problems warrants more attention to rodent exclusion than a project in a new urban fringe area with little or no history of problems. Rodent control should be considered during the preconstruction and construction phases. Infestations at these times are common and sometimes even include larger animals such as skunks and opossums. Contracts should require that contractors maintain a clean and debris-free site.

If the area is known to have heavy rat and/or mouse problems, use exterior surface materials that have a hard, smooth surface on at least the lower levels that will be subject to contact with the ground, ornamental plantings, fences, and other potential areas of rodent harborage. A viable alternative is to utilize a smooth-surfaced decorative band 14 to 18 inches (35 to 46 cm) wide around the structure above the rodent access height, in order to prevent rodents from climbing up exterior walls. Tightly rodent-proof sewer, electrical, communication, water, and natural gas services, as well as exterior doors and windows. Loading docks should have exclusion devices, automatic door-closing devices, and good construction materials that preclude rodent climbing and entry. Stairs to the dock area should have a tight-fitting personnel door far enough from the dock that rodents cannot jump from stairs to the dock. Dock bumper pads should be high enough (30 to 36 inches; [76 to 92 cm]) to avoid being used as steps by rodents.

Another consideration is the building's interior design and intended use. Office buildings with tight-fitting interior doors, tightly sealed wall voids and utility access areas, and no food or water sources are less attractive to rodents than food handling facilities, apartments, hospitals, and warehouses. Pallets commonly used in warehouses provide good harborage for rodents and should be rotated regularly. Coolers and other food storage areas should be centrally located and, if possible, in sealed rooms, separate from other warehouse goods. This confines rodent exclusion to a small area and provides for better observation if problems arise. Even the clutter of machinery, parts, and nonfood stored goods may attract rodents as harborage if food and water are nearby.

Containers for refuse disposal, including bulk dumpsters, should have tight lids. They should be kept clean and tightly sealed.

Earthquake safety joints can provide a route from the basement to the top floor of a building. Use 1/4-inch (0.6-cm) woven/welded hardware cloth between floors in these joints to effectively stop rodent travel. Urethane foam caulk or sheet metal screws have been used to hold the hardware cloth in place without interfering with the

Fig. 23. Chimney with metal stack, heavy screen (animal excluder and spark arrestor), and tight roof to wall and Z-bar flashing joints.

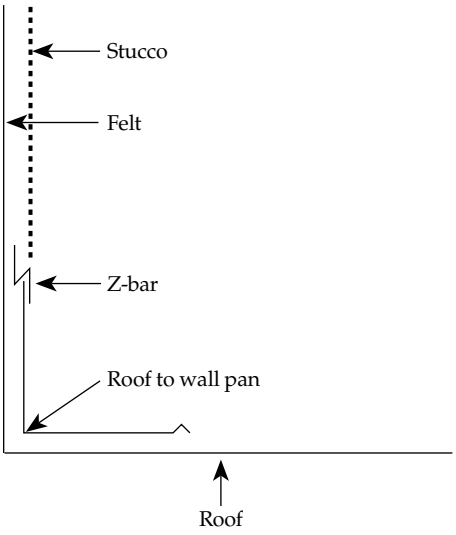


Fig. 24. Z-bar and roof-to-wall pan flashing, when properly installed, prevent rodent entry.

purpose of the safety joints. Install adjustable metal collars around utility pipes or other types of openings. They are available through building supply stores or can be easily cut from 24-gauge (or heavier) galvanized sheet metal. Double walls can best be protected near the foundation or floor area with galvanized sheet metal, hardware cloth, concrete, or other methods, as previously discussed. Use heavy (24-gauge or better) galvanized flashing, called "screed," between the siding and foundation to close any openings created by warped wood or Masonite, board and batt construction, stucco, or corrugated metal siding. Installation of fireplaces, especially zero clearance sheet metal types, poses a challenge when sealing the wall void created around and above the firebox to the roof. This area must be solidly sheeted with sheet rock or dry wall, and a metal collar called a draft stop must be used at the ceiling and roof lines. When tightly fitted, it serves to prevent rodent movement. It is also imperative that good, tight Z-bar and roof-to-wall pan flashing is properly installed around the outside of the chimney. A metal cap and secure heavy mesh screen should be installed to prevent bird or small mammal entry (Fig. 23). There are many types of metal flashing. The Z-bar flashing is installed so that it is under the felt paper and then bends outward to overlap the roof-to-wall flashing that rests against the roof and wall in an L shape (Fig. 24).

Roofs and eaves often have openings large enough for raccoons and pigeons, as well as for small rodents to enter. Many of these problems in single-family residences and apartments seem to occur where roof lines change angles or elevations, leaving an area under the eaves that is hard to fit with siding. Problems are especially common where the proper roof-to-wall and Z-bar flashing are not tightly cut and installed during initial construction. Shingle or tile roofs are sometimes a problem when they butt up against a wall or around roof vents and at roof edges. Tile and shingles are less of a problem if solid sheathing underlies the roofing material and adjacent walls have properly installed metal flashing. Tile on roofs must be well placed to avoid gaps and the ends should all be sealed with preshaped metal (commonly called "bird stop," Fig. 25) or tile fillers. All other gaps should be filled with concrete grout.

Vents must have openings of 1/4 x 1/4 inch (0.6 x 0.6 cm) or less to prevent house mouse entry (Fig. 26). There are many different types of vents for specialized placement. They include gable vents, exhaust vents, roof vents, foundation vents, and many others. The

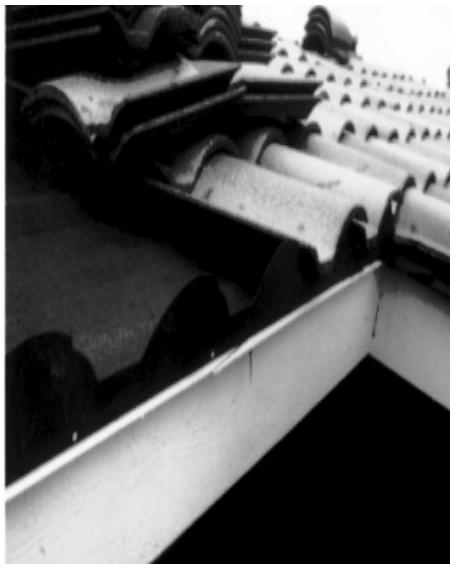


Fig. 25. "Bird stop" shaped metal for tile roofs to prevent rodent and bird entry.

Fig. 26. A side wall exhaust vent with 1/4-inch hardware cloth.

building industry has had a problem getting good-quality vents with strong 1/4 inch galvanized hardware cloth properly fastened in place. Many manufacturers are using nongalvanized hardware cloth or light screen wire, and others are simply shaping the wire into place with no fastening method used or using light spot-welding spaced too far apart, allowing the screen to be pushed away from the housing of the vent.

Openings larger than 1/4 inch x 1/4 inch (0.6 x 0.6 cm) can be used if air flow is inhibited, but the vent should be located to prevent exposure to

Fig. 27. Soft (upper) roof jack under tile.

rodents. This can easily be accomplished on roofs with smooth sheet metal raised 40 inches (1 m) or higher, constructed in a manner to avoid rough edge ribs or other surfaces that rodents can climb. Place vents on the sides of buildings at least 40 inches (1 m) above the ground level, fences, or shrubs. Use a smooth surface around the vent if the wall material has a rough texture.

Poorly installed roof jacks are a common entry point for rodents. Tile and shake shingle roofs require the use of double jacks, one rigid and the other often soft or flexible. The solid jack is installed over one layer of roofing felt and the sheeting or other substrate, and an overlapping piece of felt is then layered over the jack. The second jack is placed between the layers of roofing (tile or shingles, Fig. 27). When rigid metal is used for the upper (second) jack, gaps left between the tile and the metal should be grouted to prevent rodent or bird entry or nesting.

Permanent Bait/Census Stations. Another method that can be used to prevent the build-up of rodent populations is the installation of permanent rodent "service access areas" around the exterior of buildings. These cupboard-type areas can be built at ground level into walls or foundations near loading docks, trash areas, near utility service panels, corners, or rear alleys. The stations should be large enough to contain an automatic multiple-capture mouse trap (Ketch-All™ or Tin Cat™) and a bait station containing toxic baits. Placebo baits can be used to monitor rodent population pressure. The panel door should have tamper-resistant screws, bolts, or locks and have two 2 1/2- x 2 1/2-inch (6.4- x 6.4-cm) openings at ground level to allow entry by rats and mice.

For additional information on the control of commensal rodents, see the chapters **House Mice, Norway Rats,** and **Roof Rats.**

Acknowledgments

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Rex E. Marsh
Specialist in Vertebrate Ecology
(retired)
Department of Wildlife, Fisheries
and Conservation Biology
University of California
Davis, California 95616

BELDING'S, CALIFORNIA, AND ROCK GROUND SQUIRRELS

Fig. 1. Belding's ground squirrel, *Spermophilus beldingi* (left)

Fig. 2. California ground squirrel, *Spermophilus beecheyi* (right)

Damage Prevention and Control Methods

Exclusion

Limited usefulness and costly.

Cultural Methods

Flood irrigation and deep tillage may help discourage ground squirrels.

Habitat Modification

Eliminate brush, rock piles, and old unused farm machinery that serve as harborage for the California ground squirrel.

Frightening

None are effective.

Repellents

None are very effective.

Toxicants

Zinc phosphide.

Anticoagulants (diphacinone and chlorophacinone).

Cholecalciferol (state registration only for rock squirrels).

Fumigants

Aluminum phosphide.

Gas cartridges.

Trapping

Box-type traps (kill and live catch).

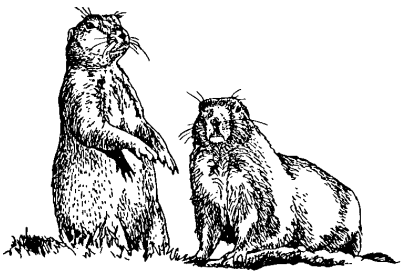
Conibear® traps.

Shooting

Limited effectiveness.

Other Methods

Burrow ripping following control.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

B-151

Introduction

Twenty-three species and 119 subspecies of ground squirrels exist in the United States (Hall 1981). At least 10 species can be of considerable economic importance to agriculture or have a significant impact on public health. This chapter covers the three species found in the far west and southwest. All three species range over extensive regions. While the California (*Spermophilus beecheyi*) and the Belding's (*S. beldingi*) ground squirrels are considered pests over large agricultural areas, they are not pests throughout their entire range. The rock ground squirrel (*S. variegatus*) is not a major pest but is important because of its involvement in the spread of plague.

The California and rock ground squirrels are closely related, belonging to the same subgenus, *Otospermophilus*. They are similar in general size and body configuration. The Belding's ground squirrel, more commonly referred to as just the Belding ground squirrel, is substantially different in appearance from the California and rock squirrels.

Identification

The Belding ground squirrel (Fig. 1) is medium-sized with a stocky build and short, furry (but not bushy) tail. It is brownish gray to reddish brown in color, and has no stripes, mottling, or markings of any type. The underside of the body is dull cream-buff, paling on the throat and inner sides of the legs. Coloration varies somewhat with subspecies. The body is about 8 1/2 inches (21.6 cm) long, with a 2 1/2-inch (6.4-cm) tail. The ears are small and not prominent.

The California ground squirrel (Fig. 2) is 10 inches (25.4 cm) long and slightly larger than the Belding ground squirrel. It has a moderately long (6 1/2-inch [16.5-cm]) semi-bushy tail. Ears are tall and conspicuous, with some exceptionally long hairs at the tips. The fur is brownish gray and dusky, with a flecked or mottled and grizzly appearance. Fur markings vary with subspecies. The Douglas subspecies (*S. b. douglasii*), for example, has a blackish brown wedge-shaped patch in the middle of the back between the shoulders, which readily distinguishes it from the other subspecies.

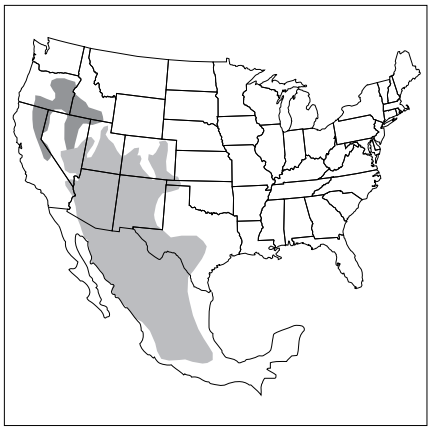


Fig. 3. Range of the Belding's (dark) and rock ground squirrels (light) in North America.

Fig. 4. Range of the California ground squirrel in North America.

The rock ground squirrel is a large-sized, heavy-bodied, ground squirrel (10 1/2 inches [26.7 cm] long) with a moderately long (8-inches [20.3-cm]) bushy tail. Large prominent ears extend above the top of the head. The fur is grayish, brownish gray, or blackish and is mottled with light gray or whitish specks or spots; coloration varies with subspecies. This ground squirrel resembles the California ground squirrel in many ways, but is somewhat larger and has a longer and bushier tail. The ranges of the rock and the California ground squirrels do not overlap; hence the two squirrels cannot be confused with one another.

Range

The Belding occupies the northeastern part of California, extending northward into eastern Oregon and eastward into the southwestern portion of Idaho (Fig. 3). It also ranges into the north-central portion of Nevada. It is the most numerous and troublesome squirrel in Oregon and northeastern California.

The California ground squirrel's range extends along the far west coast from northern Mexico northward throughout much of California, the western half of Oregon, and a moderate distance into south-central Washington (Fig. 4). This species is absent from the desert regions of California. It is the most serious native rodent pest in California, especially the subspecies *S. b. fisheri* and *S. b. beecheyi*, which occupy the Central Valley and the coastal region south from San Francisco.

The rock squirrel's range covers nearly all of Arizona and New Mexico. It extends eastward into southwestern Texas and northward into southern Nevada, and covers approximately two-thirds of Utah and Colorado. More than half of its range extends south into Mexico (Fig. 3).

Habitat

The large ranges of these three species cut across highly varied habitat. The habitat discussed here is more or less typical and the one most often associated with economic losses.

Belding ground squirrels live mainly in natural meadows and grasslands but are adaptive to alfalfa, irrigated pastures, and the margins of grain fields. At higher elevations they may occupy meadows in forested areas, but they avoid forests or dense brushlands.

California ground squirrels occupy grasslands and savannah-like areas with mixtures of oaks and grasslands. They avoid moderate to heavily forested areas or dense brushlands. They generally prefer open space, but they are highly adaptable to disturbed environments and will infest earthen

dams, levees, irrigation ditch banks, railroad rights-of-way, and road embankments, and will readily burrow beneath buildings in rural areas. They thrive along the margins of grain fields and other crops, feeding out into the field.

Rock squirrels inhabit rocky areas, hence their name. They live in rocky canyons or on rocky hillsides in arid environments, but they adapt to disturbed environments and will live along stone walls and roadside irrigation ditches, feeding out into cultivated fields.

Food Habits

Ground squirrels are essentially herbivores, but insects sometimes make up a very small portion of their diet. The California ground squirrel, and possibly the other two, will consume eggs of small ground-nesting birds, such as quail. Ground squirrels are known to cannibalize their own kind and sometimes scavenge on road kills of squirrels or other vertebrate species. This, however, represents a very small part of their overall diet.

All three species do well in the absence of free water, even in the drier regions of the west. They obtain needed water from dew or succulent vegetation, plant bulbs, and bark. If water is available, they will sometimes be seen drinking, but the presence of a stream or stock reservoir does not offer any special attraction for the squirrels.

Ground squirrels feed almost exclusively on green vegetation when they emerge from hibernation and throughout their gestation and lactation period. As the grasses and herbaceous vegetation begin to dry up in arid climates and to produce seed, the squirrels switch to eating fruit or seed for the majority of their diet. With the California ground squirrel this switch is dramatic; a complete change occurs over as short a period as 2 weeks. Using their cheek pouches for carrying food items, the California and rock ground squirrels are highly prone to hoarding and caching food. The Belding is rarely seen in this activity.

The Belding ground squirrel feeds extensively on the leaves, stems, and seeds of wild and cultivated grasses. Its diet, more than that of the other species discussed in this chapter, tends to change less dramatically and remains heavily slanted toward green succulent vegetation rather than seeds. This, in part, is because of a short active period (from February to July) at higher elevations where food is of high quality and plentiful, and few seeds may have matured by the date the squirrels start into hibernation. The lack of seeds in their diet creates significant squirrel control problems because commercial squirrel baits use cereal grains as the base of their bait, hence the bait may be poorly accepted by the squirrels. The Belding also consumes flowers, stems, leaves, and roots of herbaceous plants, depending on its habitat. It consumes seeds and fruit of mature plants in greater quantities in regions where the hibernation period is delayed until late summer or fall.

The California ground squirrel feeds extensively on the leaves, stems, and seeds of a wide variety of forage grasses and forbs, depending on the availability in the area. In oak savannah habitat, acorns are a favorite food. Thistle seeds are also highly preferred. All grains and a wide variety of other crops are consumed in cultivated areas by this opportunistic feeder.

The food of the rock squirrel is varied, depending on the native vegetation of the region. It eats many kinds of grasses and forbs. Acorns, pine nuts, juniper berries, mesquite buds and beans, and fruit and seeds of various native plants, including cactus, make up much of its diet.

General Biology, Reproduction, and Behavior

All species of ground squirrels dig burrows for shelter and safety. The burrow systems are occupied year after year and are extended in length and complexity each year. Each system has numerous entrances which are always left open and never plugged with soil. The California and rock ground squirrels are more colonial in their habits. A number of squirrels occupy the same burrow system. The Belding ground squirrel is somewhat less colonial and its burrows are more widely dispersed.

Ground squirrels are rapid runners and good climbers. Of the three species, the California and rock ground squirrels are the most prone to climbing. When scared by humans or predators, ground squirrels always retreat to their burrows.

Ground squirrels are hibernators. Most or all of the adult population goes into hibernation during the coldest period of the year. Squirrels born the previous spring may not go into complete hibernation during the first winter. In hot arid regions they may estivate, which is a temporary summer sleep that may last for a few days to a couple of weeks.

Male California and Belding squirrels generally emerge from hibernation 10 to 14 days prior to the females. The reverse is reported for rock squirrels. Breeding commences shortly after emergence from hibernation. Breeding is fairly well synchronized, with the vast majority of the females in the area bred over about a 3-week period. Exact breeding dates may vary from region to region depending on weather, elevation, and latitude. Those farthest north and at the higher elevations are latest to emerge from hibernation and to breed. Gestation is 28 to 32 days, and the young are born in a nest chamber in the burrow system. The young are born hairless with their eyes closed. They are nursed in the burrow until about 6 to 7 weeks of age (about one-third adult size), when they begin to venture above ground and start feeding on green vegetation. Only 1 litter is produced annually.

The litter size of the California ground squirrel averages slightly over 7, while that of the rock and Belding squirrels average 5 and 8, respectively. The rodent's relatively slow annual reproductive rate is compensated by a relatively long life span of 4 to 5 years.

Damage and Damage Identification

Two of the three species included in this chapter, the California and the Belding, are considered serious agricultural pests where they are found in moderate to high densities adjacent to susceptible crops or home gardens. Rock squirrels overall are relatively insignificant as agricultural pests even though their damage may be economically significant to individual growers. All three are implicated in the transmission of certain diseases to people, notably plague. This is the major reason that rock squirrels are included in this chapter. They are all adaptive and feed on a variety of crops, depending on the ones grown in proximity to their natural habitat. Since ground squirrels are active during daylight hours, and their burrow openings are readily discernible, damage identification is generally uncomplicated.

Their burrowing activities, particularly those of the California and Belding ground squirrels, weaken levees, ditch banks, and earthen dams, and undermine roadways and buildings. Burrows can also result in loss of irrigation water by unwanted diversions, and in natural habitats they may cause accelerated soil erosion by channelling rain or snow runoff.

Burrow entrances in school playgrounds, parks, and other recreational areas are responsible for debilitating falls, occasionally resulting in sprained or broken ankles or limbs. Burrows in horse exercising or jumping arenas or on equestrian trails can cause serious injuries to horses and to their riders if thrown.

The Belding ground squirrel, under favorable conditions, reaches incredible densities, often exceeding 100 per acre (247/ha). Extensive losses may be experienced in range forage, irrigated pastures, alfalfa, wheat, oats, barley, and rye.

The California ground squirrel, where numerous, significantly depletes the forage for livestock, reducing carrying capacity on rangeland as well as irrigated pasture land. All grains, and a wide variety of other crops, are consumed in agricultural regions by this opportunistic feeder. Almonds, pistachios, walnuts, apples, apricots, peaches, prunes, oranges, tomatoes, and alfalfa are subject to extensive damage. Certain vegetables and field crops such as sugar beets, beans, and peas are taken at the seedling stage, and orchard trees are sometimes injured by bark gnawing.

Rock ground squirrels consume peas, squash, corn, and grains of all kinds. They also feed on various fruit, including apples, cherries, apricots, peaches, pears, and melons, primarily to obtain their seed. They sometimes dig up and consume planted seed. Rock squirrels are not major pests, however, because their preferred natural habitat infrequently adjoins cultivated crops.

Legal Status

The three species of ground squirrels discussed in this chapter are generally regarded as pests and, as such, are not protected. Local laws or regulations should, however, be consulted before undertaking lethal control.

Be aware that several of the numerous ground squirrel species are on the threatened or endangered species lists. Any control of pest species must take into consideration the safeguarding and protection of endangered ground squirrels and other rodent species.

Damage Prevention and Control Methods

Exclusion

Squirrels can be excluded from buildings with the same techniques used to exclude commensal rats (see **Rodent-proof Construction and Exclusion Methods**). Use sheet metal cylinders around tree trunks to prevent loss of fruit or nut crops.

While fences can be constructed to exclude squirrels, they aren't usually practical because of their expense. Ground squirrels can readily dig beneath fences that are buried several feet (m) deep in the soil. Sheet metal caps atop a 4-foot (1.2 m) wire mesh fence will prevent them from climbing over. For a fence to remain squirrel-proof, the squirrels that burrow near the fence should be eliminated. Experiments with a temporary low electric fence have been shown to seasonally discourage California squirrels from invading research or small garden plots from outside areas.

Cultural Methods and Habitat Modification

Flood irrigation, as opposed to sprinkler or drip irrigation, discourages ground squirrels in orchards, alfalfa, and pasture land. It does not, however, get rid of them completely. Ground squirrels are limited by frequent tillage, especially deep discing or plowing. Squirrels compensate by living at the margins of cropland and then feeding inward from the field borders. Keep fence lines vegetation-free by discing as close as possible to them to limit the area where squirrels can thrive.

Eliminate piles of orchard prunings from the margins of the orchard to reduce cover sought by the California ground squirrel. Remove abandoned irrigation pipes or farm equipment from field margins, as well as piles of rocks retrieved from fields, to reduce sites beneath which the squirrels prefer to burrow.

Frightening

Ground squirrels cannot be frightened from their burrow sites by traditional frightening methods such as propane exploders or flagging.

Repellents

Chemical taste and/or odor repellents are ineffective in causing the squirrels to leave or avoid an area or in preventing damage to growing crops. Seed treatment repellents may offer some limited protection to newly planted crops and may be state registered for special local needs. Thiram is an example of a taste repellent sometimes used as a seed protectant.

Toxicants

Rodenticide-treated baits are the most economical of all approaches to

population reduction and, hence, have traditionally been the mainstay of ground squirrel control. Currently, zinc phosphide is the only acute rodenticide that is registered by EPA for the control of Belding and California ground squirrels. In addition, the anticoagulants diphacinone and chlorophacinone are registered (some of these labels are state registrations only). Cholecalciferol has a New Mexico state registration for rock squirrels but not for any other squirrel species. Zinc phosphide, for the most part, has replaced 1080 and strychnine for squirrel control, since the latter are no longer registered for these species.

Zinc phosphide is not always highly efficacious, but efficacy is improved if prebaiting is conducted. Bait shyness occurs when sublethal doses are consumed at the initial feeding.

The chronic slower-acting anticoagulants are more expensive to purchase and require more bait because multiple feedings are necessary to produce death. Also, death is delayed. On the other hand, these accumulative poisons do not produce bait shyness, thus providing more latitude than zinc phosphide in the timing of baiting programs.

Zinc phosphide baits are most often hand applied with a tablespoon (4 g) of bait scattered on bare ground over about 3 or 4 square feet (0.3 m^2) next to the burrow entrance. Zinc phosphide is a Restricted Use Pesticide when used in large quantities; follow label instructions as to methods and rates of application. Some labels permit broadcast application of zinc phosphide and anticoagulant baits. Use hand-cranked cyclone seeders or vehicle-mounted tailgate seeders for such applications.

Anticoagulant baits, depending on the label directions, may be hand applied like zinc phosphide but require somewhat more bait as well as repeated applications. Three or 4 applications a day on alternate days is a commonly used schedule for the California ground squirrel. Double strength diphacinone or chlorophacinone (0.01%) is most effective for broadcast applications.

PVC Inverted-T anticoagulant bait station

1. Make the bait station from PVC pipe no smaller than 4" in diameter for ground squirrels.
2. The long, upright end, 24" to 30", of the "T" is a bait reservoir. Keep this end upright by attaching it to a fence post, building, tree, stake, etc. After filling with bait, place a plastic cap on the end to keep moisture from reaching bait.
3. Keep bait in the station at all times during the control program.

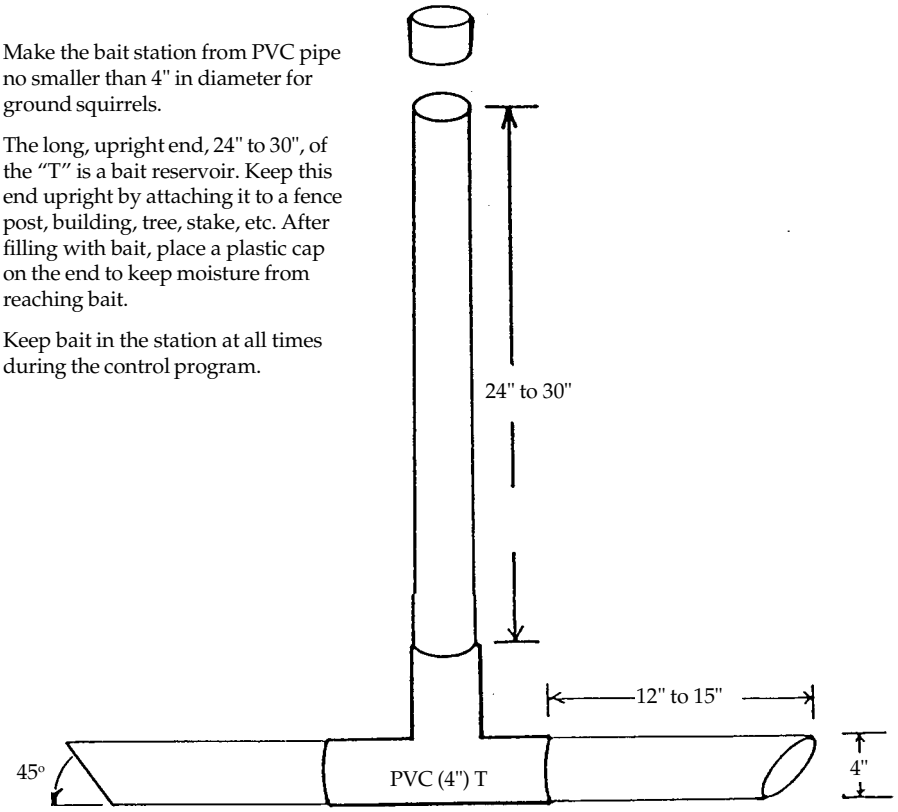


Fig. 5. Commonly used inverted "T" ground squirrel bait station made of 4-inch (10-cm) PVC pipe. Stake secures station in upright position.

Anticoagulant baits are most often exposed in bait boxes, where a continuous supply of bait will be available to the squirrels. Bait boxes may be made of rubber tires, or metal, plastic, or wood containers. Many are made of sections of 4-inch (10-cm) plastic irrigation pipe designed in an inverted "T" configuration (Fig. 5). Squirrels are often reluctant to enter the bait boxes or stations for a few days, and it may take several additional weeks before all the squirrels are killed and bait consumption ceases. Caching of bait does occur, especially with California ground squirrels, and is more prevalent in the late summer and fall of the year. Apply baits earlier in the year to save bait.

The timing of baiting programs is critical to good control. For maximum effectiveness, bait only when all the squirrels are out of hibernation or estivation and are actively feeding on seed. Commercial baits are prepared on grain or pelletized cereals.

To assure good bait acceptance prior to an extensive control program, acceptance should be tested by scattering tablespoons of bait next to a few burrows. If all of the bait is gone the next day, good bait acceptance is indicated. Bait acceptance is especially important with zinc phosphide or cholecalciferol, both of which require just a single feeding to produce death. Good acceptance avoids poor control and possible bait or toxin shyness, which will adversely affect repeat control efforts.

If acceptance of cereal baits is less than adequate (either prebait or test baits are not consumed), then zinc phosphide application should be delayed until bait acceptance is improved, or not applied at all in favor of other control options. Anticoagulant baits placed in bait stations can sometimes be an effective option where zinc phosphide acceptance is marginal. Squirrels may learn to take the anticoagulant bait over time and, since they are

accumulatively poisoned with no bait shyness, control will not be jeopardized by marginal feeding as long as feeding continues over a number of days.

Fumigants

Ground squirrels can be killed in their burrow systems by introducing one of several toxic or suffocating gases, such as phosphine gas or carbon monoxide. Fumigation should be conducted when the squirrels are out of hibernation. Hibernating squirrels plug their burrows with soil to separate themselves from the outside, whereby they are safe from the lethal consequences of the toxic gas.

Burrow fumigation has a distinct advantage over toxicants and trapping in that it is linked to no behavioral trait other than that squirrels seek the cover of their burrows when disturbed. Fumigation is most effective following ground squirrel emergence from hibernation and before the squirrels have time to reproduce. Recently born squirrels, too young to venture above ground to be baited or trapped, are effectively controlled by fumigants.

Gas cartridges are easy to use and are available from commercial manufacturers and distributors or from the USDA supply depot at Pocatello, Idaho. They consist of cylinders of combustible ingredients with a fuse. Place the cartridge at the entrance of the burrow and light the fuse; then, with a shovel handle or stick, push the lit cartridge as far back into the burrow as possible. Quickly cover the burrow entrances with soil or sod and tamp tight to seal in the toxic gases. The best results are obtained when soil moisture is high, because less gas will escape the system. Do not use near buildings, because high temperatures may cause fires.

The method for using aluminum phosphide differs considerably from that for gas cartridges. Place the prescribed number of aluminum phosphide tablets or pellets as far back into the burrow opening as possible. Then insert a wad of crumpled newspaper into the burrow and seal it tightly with soil.

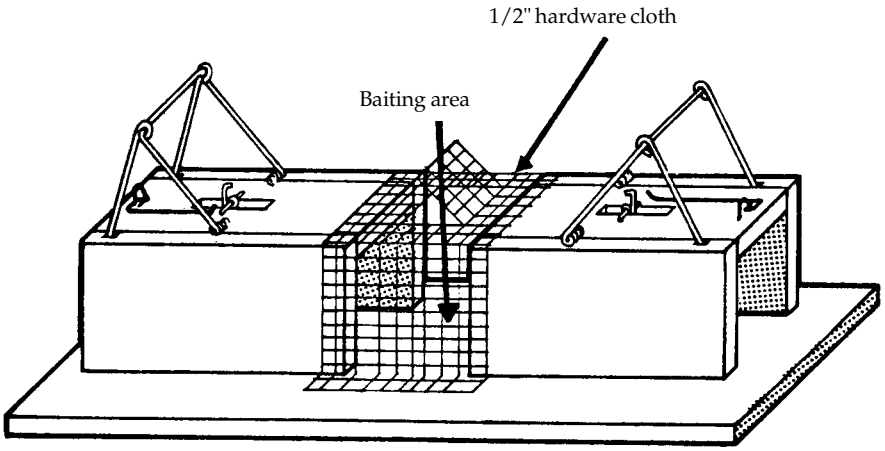
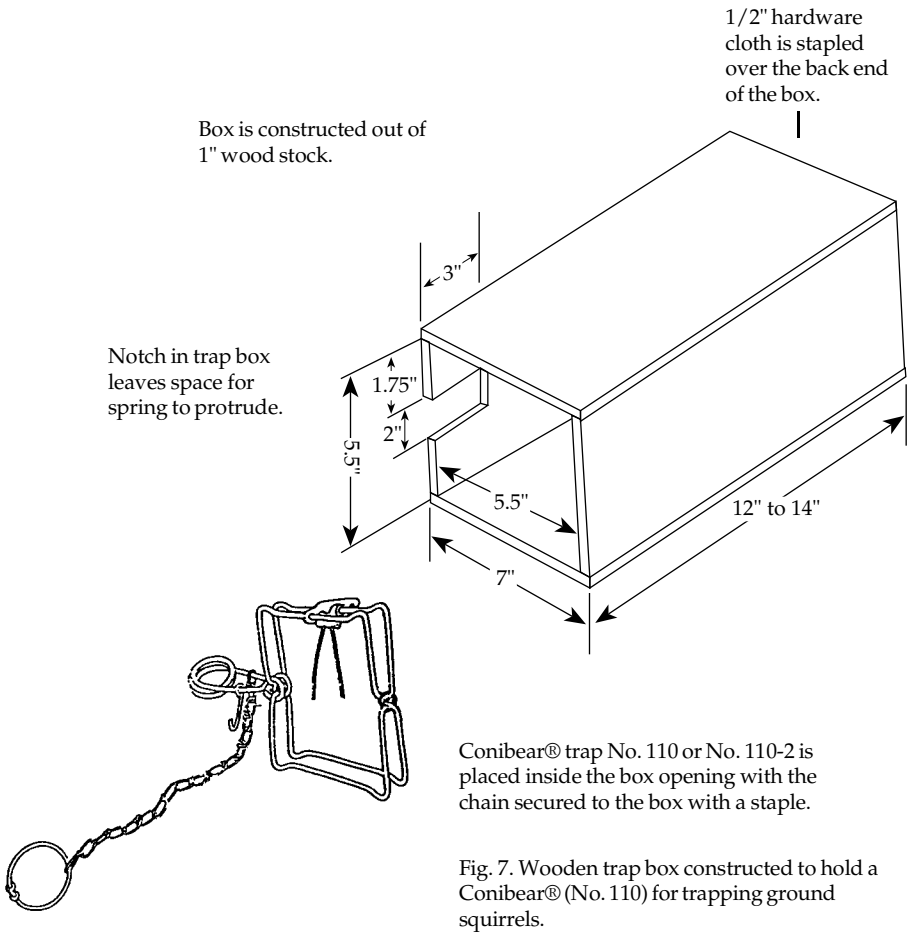


Fig. 6. Two modified pocket gopher traps mounted on a single board with a common bait area are very effective for trapping ground squirrels.



Conibear® trap No. 110 or No. 110-2 is placed inside the box opening with the chain secured to the box with a staple.

Fig. 7. Wooden trap box constructed to hold a Conibear® (No. 110) for trapping ground squirrels.

The newspaper plug prevents the soil from covering the pellets or tablets, permitting them to react more readily with the atmospheric and soil moisture to produce the lethal phosphine gas. Aluminum phosphide is a Restricted Use Pesticide. Knowledge of its proper handling is required.

Trapping

Although labor-intensive, trapping can be highly effective in reducing low to moderate squirrel populations over relatively small acreages or where poison baits may be inappropriate. Trapping can be conducted any time the squirrels are out of hibernation. For

humane reasons, avoid the period when the females are lactating and nursing their young. Trapping prior to the time the young are born is biologically most sound from a control point of view.

An initial investment of an adequate number of traps is required, but, if properly maintained, traps will last many years. In agricultural situations, 100 or more traps may be needed to start with. A good rule of thumb is one trap for every 10 to 15 squirrels present. If too few traps are used, the trapper becomes discouraged long before the squirrel population is brought under control.

Several types of traps are used for ground squirrels. A modified pocket gopher kill-type box trap has been used to trap the California ground squirrel for many years (Fig. 6). It can be set near burrow openings, in trails, or in trees where nut or fruit crops are being damaged. Bait traps with walnuts, almonds, slices of orange, or pieces of melon. With all types of squirrel traps, the control period will be more decisive and maximum results obtained if the traps are left unset or tied open and baited for several days to permit the squirrels to get used to them. Then rebait and set all the traps.

Unbaited Conibear® traps (No. 110 or No. 110-2) with a 4 1/2 x 4 1/2-inch (11.4 x 11.4-cm) jaw spread are effective when set over the burrow entrances. This method is not useful where squirrels are living in the rocks or in rocky situations where burrow entrances are inaccessible. A special trap box (Fig. 7) will facilitate the use of Conibear® traps that cannot be set over burrow openings. These make the Conibear® traps more versatile as they can be set in trails or near burrow openings. Conibears in trap boxes must be baited to entice the squirrels into the trap. If the squirrels are readily eating seed, then wheat, oats, or barley can be used as bait. The Conibear® trap has virtually replaced all uses of leghold traps in the far west for ground squirrel control.

Live-catch wire or wooden traps can be used to trap ground squirrels in residential areas where kill-type traps are considered inappropriate from a public relations point of view. The captured squirrels should be removed from the site and humanely euthanized with carbon dioxide. Releasing live ground squirrels elsewhere is illegal in some states, uneconomical, and rarely biologically sound in any holistic approach to pest management or disease prevention.

Shooting

If local laws permit, shooting with a .22 rifle may provide some control where squirrel numbers are low, but it is very time-consuming. For safety considerations, shooting is generally limited to rural situations and is considered too hazardous in many more populated areas, even if legal. Ground squirrels that are repeatedly shot at become very hunter/gun-shy. Rarely can one get close enough to use a pellet gun effectively, and the noise of a shotgun scares the squirrels sufficiently that after the first shot, the remaining squirrels will be very hesitant to emerge from their burrows.

Other Methods

Once ground squirrels have been removed from a crop area, their reinvasion can be substantially slowed by ripping up their old burrow sites to a depth of at least 20 inches (51 cm), preferably deeper. One to three ripping tongs mounted on the hydraulic implement bar of a tractor works well. Spacing between rips should be about 3 feet (1 m). This approach is not suitable where the burrows are beneath large rocks or trees.

Economics of Damage and Control

In one experimental study, 12 California ground squirrels were found to consume about 1,000 pounds (454 kg) of range forage. In another study, it was calculated that 200 ground squirrels consumed the same amount as a 1,000-pound (454-kg) steer. In spite of control, the California ground squirrel has caused an estimated 30 to 50 million dollars of agricultural and other damage annually in California alone.

A northern California study of the Belding's ground squirrel showed that 123 squirrels per acre (304/ha) destroyed 1,790 pounds of alfalfa per acre (2,006 kg/ha) over one growing season.

Little seems to be recorded concerning the extent or amount of economic damage caused by the rock squirrel. Economic loss is believed to be relatively low, but the rock squirrel's role in the transmission of plague makes it important from a public health viewpoint.

The cost of control varies with the situation, squirrel density, and methods employed. Baiting with an acute toxicant like zinc phosphide is the most economical method, with 1 pound (454 g) of bait ample for placement adjacent to 60 burrow entrances. The use of anticoagulant baits is considerably more expensive, requiring anywhere from 1/2 to 1 1/4 pounds (227 to 568 g) of bait per squirrel. The expense of bait stations would be an added cost.

The use of burrow fumigants is about 8 to 10 times more expensive for materials and labor than the use of zinc phosphide baits. Trapping is half again more expensive than burrow fumigation.

Acknowledgments

Figures 1 and 2 from T. I. Storer (1958).

Figures 3 and 4 adapted from E. R. Hall (1981), by David Thornhill, University of Nebraska-Lincoln.

Figure 5, 6, and 7 adapted from R. E. Marsh by David Thornhill.

For Additional Information

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Editors
Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Leonard R. Askham
Professor Emeritus
Department of Horticulture and
Landscape Architecture
Washington State University
Pullman, Washington 99164-6414

FRANKLIN, RICHARDSON, COLUMBIAN, WASHINGTON, AND TOWNSEND GROUND SQUIRRELS

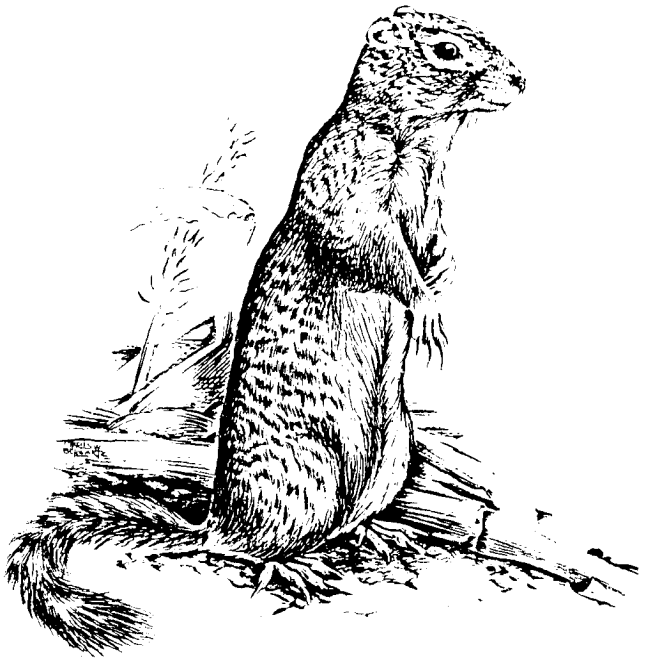


Fig. 1. Franklin ground squirrel, *Spermophilus franklinii*

Damage Prevention and Control Methods

Exclusion

Limited usefulness.

Cultural Methods

Flood irrigation, forage removal, crop rotation, and summer fallow may reduce populations and limit spread.

Repellents

None are registered.

Toxicants

Zinc phosphide.

Chlorophacinone.

Diphacinone.

Note: Not all toxicants are registered for use in every state. Check registration labels for limitations within each state.

Fumigants

Aluminum phosphide.

Gas cartridge.

Trapping

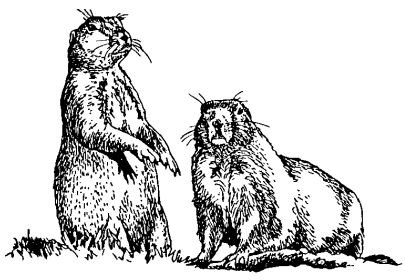
Box traps.

Burrow-entrance traps.

Leghold traps.

Shooting

Limited usefulness.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

B-159

Identification

The Franklin ground squirrel (*Spermophilus franklinii*, Fig. 1) is a rather drab grayish brown. Black speckling gives a spotted or barred effect. Head and body average 10 inches (25.4 cm) with a 5- to 6-inch (12.7- to 15.2-cm) tail. Adults weigh from 10 to 25 ounces (280 to 700 g).

The Richardson ground squirrel (*S. richardson*) is smaller and lighter colored than the Franklin. Some are dappled on the back. The squirrel's body measures about 8 inches (20.3 cm) with a tail of from 2 to 4 inches (5 to 10 cm). Adults weigh from 11 to 18 ounces (308 to 504 g).

The Columbian ground squirrel (*S. columbianus*) is easily distinguished from others in its range by its distinctive coloration. Reddish brown (rufous) fur is quite evident on the nose, forelegs, and hindquarters. The head and body measure 10 to 12 inches (25.4 to 30.5 cm) in length with a 3- to 5-inch (7.6- to 12.7-cm) tail. An average adult weighs more than 16 ounces (454 g).

The Washington ground squirrel (*S. washingtoni*) has a small smoky-gray flecked body with dappled whitish spots. The tail is short with a blackish tip. This squirrel is similar to Townsend and Belding squirrels except the latter have no spots. Head and body are about 6 to 7 inches long (15.2 to 18 cm); the tail 1.3 to 2.5 inches long (3.4 to 6.4 cm); and adults weigh 6 to 10 ounces (168 to 280 g).

The Townsend ground squirrel's (*S. townsendi*) head and body range in length from 5.5 to 7 inches (14 to 18 cm). It has a short bicolored tail about 1.3 to 2.3 inches (3 to 6 cm) long, and weighs approximately 6 to 9 ounces (168 to 252 g). The body is smoky-gray washed with a pinkish-buff. The belly and flanks are whitish.

Other species not described here because they cause few economic problems are Idaho (*S. brunneus*), Uinta (*S. armatus*), Mexican (*S. mexicanus*), Spotted (*S. spilosoma*), Mohave (*S. mohavensis*), and roundtail (*S. tereticaudus*) ground squirrels.

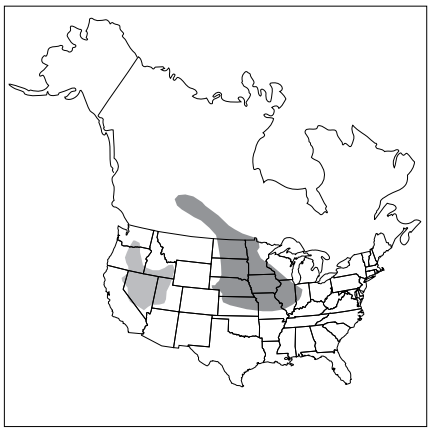


Fig. 2. Range of Franklin (dark) and Townsend ground squirrels (light) in North America.

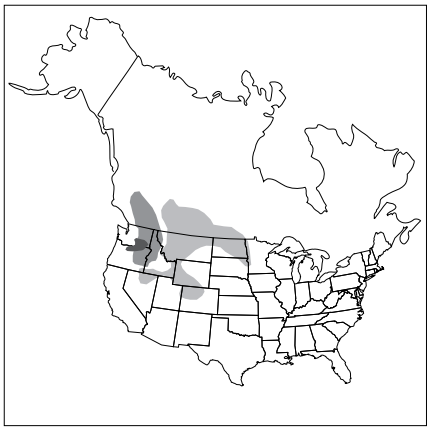


Fig. 3. Range of Richardson (light), Columbian (medium), and Washington ground squirrels (dark) in North America.

Range

Ground squirrels are common throughout the western two-thirds of the North American continent. Most are common to areas of open sagebrush and grasslands and are often found in and around dryland grain fields, meadows, hay land, and irrigated pastures. Details of each species range, which overlap occasionally, are shown in figures 2 and 3.

Food Habits

Ground squirrels eat a wide variety of food. Most prefer succulent green vegetation (grasses, forbs, and even brush) when available, switching to dry foods, such as seeds, later in the year. The relatively high nutrient and oil content of the seeds aids in the deposition of fat necessary for hibernation. Most store large quantities of food in burrow caches. Some species, like the Franklin, eat a greater amount of animal matter, including ground-nesting bird eggs. Insects and other animal tissue may comprise up to one-fourth of their diet.

General Biology, Reproduction, and Behavior

Ground squirrels construct and live in extensive underground burrows, sometimes up to 6 feet (2 m) deep, with many entrances. They also use and improve on the abandoned burrows of other mammals such as prairie dogs and pocket gophers. Most return to their nests of dried vegetation within the burrows at night, during the warmest part of summer days, and when they are threatened by predators, such as snakes, coyotes, foxes, weasels, badgers, and raptors.

The squirrels generally enter their burrows to estivate, escaping the late summer heat. They hibernate during the coldest part of the winter. Males usually become active above ground 1 to 2 weeks before the females in the spring, sometimes as early as late February or early March. A few may be active above ground throughout the year. Breeding takes place immediately after emergence. The young are born after a 4- to 5-week gestation period with 2 to 10 young per litter. Generally only 1 litter is produced each year. Densities of the ground squirrel populations can range from 2 to 20 or more per acre (5 to 50/ha).

Damage and Damage Identification

High populations of ground squirrels may pose a serious pest problem. The squirrels compete with livestock for forage; destroy food crops, golf courses, and lawns; and can be reservoirs for diseases such as plague. Their burrow systems have been known to weaken and collapse ditch banks and

canals, undermine foundations, and alter irrigation systems. The mounds of soil excavated from their burrows not only cover and kill vegetation, but damage haying machinery. In addition, some ground squirrels prey on the eggs and young of ground-nesting birds or climb trees in the spring to feed on new shoots and buds in orchards.

Legal Status

Ground squirrels generally are unprotected. However, species associated with them, such as black-footed ferrets, weasels, wolves, eagles, and other carnivores may be protected. Local laws as well as specific label restrictions should be consulted before initiating lethal control measures.

Damage Prevention and Control Methods

Exclusion

Exclusion is impractical in most cases because ground squirrels are able to dig under or climb over most simple barriers. Structures truly able to exclude them are prohibitively expensive for most situations. Sheet metal collars are sometimes used around tree trunks to prevent damage to the base of the trees or to keep animals from climbing trees to eat fruit or nut crops.

Cultural Methods/Habitat Modification

Flood irrigation of hay and pasture lands and frequent tillage of other crops discourage ground squirrels somewhat. Squirrels, however, usually adapt by building the major part of their burrows at the margins of fields, where they have access to the crop. During the early part of the season they begin foraging from the existing burrow system into the field until their comfort escape zone is exceeded. When this zone is exceeded and as the litters mature in the colony, tunnels will be extended into the feeding area. Late in the summer or fall, tillage will destroy these tunnels but will not disturb or destroy the original system at the edge of the field.

Some research has been conducted on the effect of tall vegetation on ground squirrel populations and movements. The data, while sketchy, indicate that the squirrels may move out of tall vegetation stands to more open grass fields. The addition of raptor (hawk, owl, and kestrel) nest boxes and perches around the field border or throughout the colony may reduce colony growth, but is not a reliable damage control method.

Toxicants

Zinc phosphide and anticoagulants are currently registered for ground squirrel control. Since pesticide registrations vary from state to state, check with your local extension, USDA-APHIS-Animal Damage Control, or state department of agriculture for use limitations. Additional restrictions may be in effect for areas where endangered species have been identified.

Zinc phosphide has been used for several years to control ground squirrels. It is a single-dose toxicant which, when used properly, can result in mortality rates as high as 85% to 90%. If, however, the targeted animals do not consume enough bait for mortality to occur, they become sick, associate their illness with the food source they have just consumed, and are reluctant to return to the bait. This is called "bait shyness." Repeated baiting with the same bait formulations is generally unsuccessful, particularly when tried during the same year.

Prebaiting may increase bait acceptance with treated grain baits. Prebaiting means exposing squirrels to untreated grain bait several days before using toxic grain. Conditioning the squirrels to eating this new food improves the likelihood of their eating a lethal dose of toxic grain. Prebaiting often improves bait acceptance and, therefore, control. The major disadvantage is the cost of labor and materials for prebaiting.

Zinc phosphide is classified as a Restricted Use Pesticide and as such, can only be purchased or used with proper certification from the state. Certification information can be obtained from your local Cooperative Extension or state department of agriculture office. Zinc phosphide can be absorbed in small amounts through the skin. Rubber gloves should be worn when handling the bait.

Use only fresh bait. Spoiled or contaminated baits will not be eaten by ground squirrels. Old bait may not be sufficiently toxic to be effective. If zinc phosphide baits are more than a few months old they should not be used, particularly if they have not been stored in air-tight, sealed containers, because they decompose with humidity in the air.

Chlorophacinone and diphacinone are two anticoagulant baits that have been registered in some states for ground squirrel control and have been found to be quite effective. Both are formulated under a number of trade names. Death will occur within 4 to 9 days if a continual supply of the bait is consumed. If baiting is interrupted or a sufficient amount is not maintained during the control period, the toxic effects of the chemicals wear off and the animal will recover.

Baiting should not begin until the entire population is active, 2 to 3 weeks after the first adults appear. If a portion of the population is in hibernation or estivation, only the active animals will be affected.

Bait selection should be based on the animal's feeding habits, time of year, and crop type. Ground squirrel feeding habits vary with the time of year. Grain baits may be more acceptable during the spring when the amount of green vegetation is limited. Pelletized baits using alfalfa or grass as a major constituent may be preferred later in the season.

It is important to test the acceptance of a bait before a formal baiting program begins. Place clean (untreated) grains by several active burrows. Use only grains acceptable to the animals as a bait carrier. If none of the grains are consumed, the same procedure can be repeated for pelletized baits. Several formulations may need to be tried before an acceptable bait is selected.

If control with one bait is unsuccessful, rebaiting with another toxicant may produce the desired results. This is particularly important when zinc phosphide is used. Follow-up treatments with an anticoagulant will often control the remaining animals.

Bait placement is critical. Bait should be scattered adjacent to each active burrow in the amount and manner specified on the label. It should not be placed in the burrow, because it will either be covered with soil or pushed out of the hole by the squirrels. Ground squirrels are accustomed to foraging above ground for their food and are suspicious of anything placed in their tunnel systems. All active burrows must be baited. Incomplete coverage of the colony will result in poor control success.

Where broadcast applications are not allowed, baits can be placed in spill-proof containers. Old tires have been extensively used in the past but are bulky, heavy, and time-consuming to cut apart and move. Furthermore, bait can easily be pushed out by the animals and the tires can ruin a good sickle bar or header if not removed from a field before harvest. Corrugated plastic drain pipe of different diameters cut into 18- to 24-inch (46- to 61-cm) lengths provide an inexpensive, light-weight, and easy-to-use alternative.

Bait stations should be placed in the field at about 50-foot (15-m) intervals a week or so before treatments are to begin. Once the animals use the stations frequently, baiting can begin. Not all bait stations will be used by the squirrels at the same time or with the same frequency. Each station should be checked every 24 hours and consumed or contaminated baits replaced until feeding stops. When the desired level of control has been achieved, the bait stations should be removed from the field and the old bait returned to the original container or properly disposed.

Fumigants

Fumigants are best suited to small acreages of light squirrel infestations. Most are only effective in tight, compact, moist soils over 60° F (15° C). The gas dissipates too rapidly in loose dry soils to be effective in any extensive burrow system. Ground squirrel burrow systems are often complex with several openings and numerous interconnecting tunnels. The cost of using gas cartridges may be more than eight times the cost of using toxic baits.

Fumigants registered for ground squirrel control include aluminum phosphide and gas cartridges. Cartridges may contain several combustible ingredients.

When using aluminum phosphide, place tablets at multiple entrances at the same time. Insert the tablets as far back into the burrows as possible. Water may be added to the soil to improve activity. Never allow aluminum phosphide to come into direct contact with water, because the two together can be explosive. Crumpled paper should be placed in the hole to prevent the fumigant from being pushed out of the hole by the animals or being covered by loose soil. Plug the burrow opening with soil to form an air-tight seal. Monitor the area for escaping gas and plug holes as needed.

When using gas cartridges, punch five or six holes in one end of each gas cartridge and loosen the contents for more complete combustion before use. Insert and light a fuse. Gently slide the cartridge, fuse end first, as far back into the burrow opening as possible and immediately seal the hole with soil. Do not cover or smother the cartridge. Follow all label instructions.

Phosphine gas is toxic to all forms of animal life. Inhalation can produce a sensation of pressure in the chest, dizziness, nausea, vomiting, and a rapid onset of stupor. Affected people or animals should be exposed to fresh air and receive immediate medical attention. Never carry a container of aluminum phosphide in an enclosed vehicle.

Trapping

Traps are best suited for removal of small populations of ground squirrels where other control methods are unsatisfactory or undesirable. Jaw traps (No. 1 or No. 0), box or cage traps, and burrow entrance traps may be used.

Place leghold traps where squirrels will travel over them when entering and leaving their burrows. Conceal the trap by placing it in a shallow excavation and covering it with 1/8 to 1/4 inch (0.3 to 0.6 cm) of soil. Be certain that there is no soil beneath the trap pan to impede its action. No bait is necessary.

Box or cage traps may be set in any areas frequented by ground squirrels. Place them solidly on the ground so that they will not tip or rock when the squirrel enters. Never place the trap directly over a hole or on a mound. Cover the floor of the trap with soil and bait it with fresh fruit, vegetables, greens, peanut butter, or grain. Experiment to find the best bait or combination of baits for your area and time of year. Wire the door of the trap open for 2 to 3 days and replenish the bait daily to help overcome the squirrel's trap shyness and increase trapping success.

Burrow entrance traps may also be useful. See **Thirteen-lined Ground Squirrels** for a description of this type of trap.

Shooting

Shooting may provide relief from ground squirrel depredation where very small colonies are under constant shooting pressure. It is, however, an expensive and time-consuming practice. Hunting licenses may be required in some states.

Other Methods

Gas exploding devices for controlling burrowing rodents have not proven to be effective. Propane/oxygen mixtures injected for 45 seconds and then ignited only reduced the population by about 40%. Vacuum devices that suck rodents out of their burrows are currently being developed and tested. No reliable data, however, exist at this time to confirm or deny their efficacy.

Economics of Damage and Control

Very little is known about the economic consequences of ground squirrels foraging in agriculture. A single pair and their offspring can remove about 1/4 acre (0.1 ha) of wheat or alfalfa during one season. Water lost from one canal can flood thousands of acres or cause irrigation failures. The crop loss and cost of repair can be very expensive. Prevention, by incorporating a rodent management plan into the total operation of an enterprise, far outweighs the cost of added management practices.

Acknowledgments

Figure 1 from Schwartz and Schwartz (1981).

Figures 2 and 3 adapted from Burt and Grossenheider (1976) by David Thornhill.

Some of the material included in this draft was written by C. Ray Record in the 1983 edition of *Prevention and Control of Wildlife Damage.*

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Edward C. Cleary
Associate State Director
USDA-APHIS-
Animal Damage Control
Sandusky, Ohio 44870

Scott R. Craven
Extension Wildlife Specialist
Department of Wildlife Ecology
University of Wisconsin, Madison
Madison, Wisconsin 53706

THIRTEEN-LINED GROUND SQUIRRELS

Fig. 1. Thirteen-lined ground squirrel, *Spermophilus tridecemlineatus* (formerly *Citellus* spp.)

Damage Prevention and Control Method

Exclusion

Buried galvanized hardware cloth is effective, but very expensive.

Cultural Methods

Destroy burrows and habitat by deep soil tillage.

Allow growth of tall rank vegetation.

Plant as early as conditions permit before squirrels emerge from hibernation.

Provide alternative foods in minimum-tillage fields.

Repellents

None are registered.

Toxicants

Zinc phosphide.

Fumigants

Aluminum phosphide.

Gas cartridges.

Trapping

Live traps.

Glue boards.

Wooden-base rat-sized snap traps.

Leghold and body-gripping traps.

Snares.

Shooting

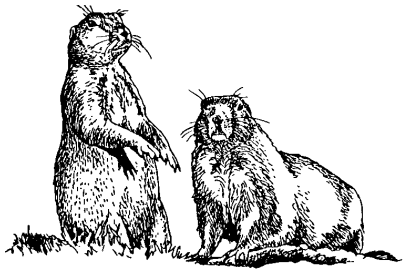
Effective if persistent.

Other Methods

Burrow flooding.

Identification

The thirteen-lined ground squirrel (Fig. 1) is a slender rat-sized rodent weighing about 8 ounces (227 g) with a length of about 10 inches (25 cm) including a tail of 3 inches (8 cm). As its name implies, 13 stripes run the length of this ground squirrel's body. Five of the light-colored lines break up into a series of spots as they progress down the back and over the rump. Five light and four dark stripes extend along the top of the head and end between the animal's eyes. The cheeks, sides of the body, and legs are yellowish, tan, or tan with an orange cast. The chest and belly are thinly covered with light tan fur. Each front foot has four toes with long slender digging claws. There are five toes on each hind foot.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

B-165

Some of the common or colloquial names for this species include "thirteen-liners," "stripers," "striped ground squirrels," "striped gophers," and "gophers."

Range

The thirteen-lined ground squirrel is a grassland animal. Its original range was limited to the prairies of the North American Great Plains. When Europeans arrived and started clearing forests and establishing pastures, the thirteen-lined ground squirrel was quick to extend its range into the new habitat. Today, it ranges from central Alberta, Manitoba, and Saskatchewan in the north to Texas and New Mexico in the south, and from central Ohio in the east to Colorado in the west (Fig. 2). The forests of the Appalachian Highlands and the Rocky Mountains have halted their east/west range expansion. There are a few colonies in Venango County, Pennsylvania, the result of introductions made in 1919.

Fig. 2. Distribution map for thirteen-lined ground squirrels. They currently occur in all or part of 22 states and 3 Canadian prairie provinces.

Food Habits

Thirteen-lined ground squirrels are omnivorous. At least 50% of their diet is animal matter — grasshoppers, wireworms, caterpillars, beetles, cutworms, ants, insect eggs, mice, earthworms, small birds, and each other. The vegetative portion of the diet includes seeds, green shoots, flower heads, roots, vegetables, fruits, and cereal grains. They rarely drink water, depending instead on water contained in their food. They cache large quantities of seeds and grass, but never meat. The cached food may be eaten during periods of bad weather or in the late autumn and early spring when other food is scarce.

General Biology, Reproduction, and Behavior

Thirteen-lined ground squirrels are strictly diurnal, coming above ground when the sun is high and the earth is warm, and returning to the warmth and safety of their burrows long before sundown. They rarely venture out of the burrow on damp, dark, or overcast days. When they venture out, they will often stand upright, with front paws held close to the chest, surveying their domain. If danger threatens, they run, with tail held horizontally, to the nearest burrow. The inconspicuous 2-inch (5-cm) diameter burrow opening is often concealed by vegetation and rarely has soil scattered in front of it like a woodchuck's burrow. The main entrance plunges down 6 inches (15 cm) or more before angling off into a complex system of galleries and side entranceways. The nesting chamber, about 9 inches (23 cm) in diameter and lined with fine dry grass, is located somewhat deeper than the main burrow system. The thirteen-lined ground squirrel's natural enemies include just about all predators, especially hawks, badgers, weasels, foxes, coyotes, bull snakes, and black snakes.

Thirteen-lined ground squirrels begin hibernation in September or early October and emerge between late March and early May in the northern portions of their range. In southern Texas, they have been observed above ground as late as October 27 and as early as January. Males usually begin hibernation earlier in the fall and emerge earlier in the spring than females. When they hibernate, their body temperature is generally within 3° C of the ambient air temperature. When active, their body temperature can vary 8 to 10° C, without ill effect.

Mating activity begins within 2 weeks after the squirrels emerge from hibernation. Both sexes are sexually active for about 2 weeks. After a gestation period of 28 days, 3 to 14 (average 10) blind, naked, and toothless young are born. Only 1 litter is produced per year. Young ground squirrels weigh about 1/10 ounce (3 to 4 g) at birth. Their stripes begin to appear after about 12 days and their eyes open 28 to 30 days after birth. Young squirrels are weaned and on their own after 6 to 12 weeks. Thirteen-lined ground squirrels are sexually mature at 9 or 10 months of age.

Damage and Damage Identification

The thirteen-lined ground squirrel's preference for insects and field mice may provide some benefit to the agricultural community. Large concentrations of these ground squirrels in pastures, fields, and gardens can, however, cause loss of forages and crops. They dig up newly planted seeds, clip emerging plant shoots, and pull overripening wheat, barley and oats to eat the grain. They will readily feed on commonly grown home or truck garden vegetables, often damaging much more than they consume.

Thirteen-lined ground squirrels will invade golf courses, parks, lawns, athletic fields, cemeteries, and similar wide open grassy sites. Their burrowing and feeding activity can cause major economic and aesthetic damage in such places.

Legal Status

Thirteen-lined ground squirrels are not protected by federal law. They are protected by some state and provincial regulations (Table 1).

Table 1. Status of the thirteen-lined ground squirrel in the United States and Canada.

Alberta[1]	Nebraska[1]
Arizona[1]	New Mexico[1]
Arkansas[7]	North Dakota[1]
Colorado[1]	Ohio[1]
Illinois[1]	Oklahoma[1]
Indiana[1]	Pennsylvania[3, 6]
Iowa[3]	Saskatchewan[1]
Kansas[1]	South Dakota[1]
Manitoba[1]	Texas[5]
Michigan[4]	Utah[1]
Minnesota[1]	Wisconsin[1]
Missouri[3]	Wyoming[2]
Montana[1]	

[1]No restriction on taking or possessing.
[2]Classed as wildlife, but no restriction on some or all methods of take.
[3]May be taken only with special state permit.
[4]State permit needed for some methods of take such as poisoning, fumigation.
[5]May be taken only when causing or about to cause damage.
[6]State threatened species.
[7]Believed extinct in state.

Damage Prevention and Control

Exclusion

Exclusion is expensive and generally practical only in situations where cost is not a primary concern. Thirteen-lined ground squirrels are very good at digging and climbing. They can be kept out of electrical substations or similar installations with hardware cloth topped with sheet metal. Most electrical substations or other secured installations are enclosed by a chain link fence that can be made ground squirrel-proof. Dig a trench 18 inches (45 cm) wide and 18 inches (45 cm) deep around the installation next to the outside of the existing fence. Install galvanized 0.5-inch (1.3-cm) or smaller mesh hardware cloth (6 foot [2 m] wide) across the bottom and up the side of the trench nearest the existing fence, continuing 3 feet (1 m) up the fence. Backfill the trench. Securely attach the hardware cloth to the chain-link fence. Attach a piece of sheet metal, 2 to 3 feet (61 to 90 cm) wide, to and above the hardware cloth. Adjust all gates to fit within 0.5 inches (1.27 cm) of the support post and the ground. It may be necessary to install a cement threshold to keep squirrels from digging under the gate.

Cultural Methods

Activity in fields and gardens can be discouraged by deep soil cultivation, which destroys burrows and changes the habitat. Allow grassy areas to grow as tall and as dense as possible, consistent with local land use practices. Such vegetation discourages ground squirrels but may encourage population of other small mammals, such as voles (*Microtus* spp.). Plant crops as early as possible, before the squirrels emerge from hibernation, to reduce losses to seeds and seedlings.

Deter ground squirrels and other small mammals from feeding on crop seeds and seedlings by providing them with an alternative food source. At planting, broadcast 4 bushels of cracked corn per acre (0.35m^3/ha) over the outside four to eight rows adjacent to ground squirrel habitat. It also may be necessary to spot treat fields in areas where damage is expected or observed, especially if conservation tillage is employed.

Pesticides

Before using any pesticide, read and follow all label directions. Many of the pesticides used to control thirteen-lined ground squirrels are Restricted Use Pesticides that may only be sold to and used by certified pesticide applicators or persons working under their direct supervision, and only for those uses covered by the licensed applicator's certification. Some of the pesticides mentioned may not be registered for every use in all states or provinces. Contact your local cooperative extension agent, USDA-APHIS-ADC, state or provincial pesticide regulatory agency, or state or provincial fish and wildlife department for information regarding special permit requirements or endangered species restrictions. Specific use instructions can be found on the individual product labels. Only general use comments will be presented here. Check the **Pesticides** section in this handbook for sample labels.

Repellents

None are registered.

Toxicants

Zinc phosphide-treated baits can be applied by hand in, or broadcast on noncrop areas such as rights-of-way, golf courses, ornamental plantings, nurseries, parks, lawns, field borders, and ditch banks. Apply 1 teaspoon (4 g) of untreated bait (clean oats or other grains similar to the bait) around each active burrow 2 to 3 days before applying treated bait to ensure good acceptance of toxicants. Apply prebait on a bright, warm, sunny day when the ground squirrels are most active. Allow material to fall through the grass to the ground. Do not apply to bare ground and do not apply in piles. Two to 4 days later, after the prebait has been eaten, place 1 teaspoon (4 g) of treated bait in the same locations. Do not apply prebait or bait near homes, where food or feed is grown, over water, on roads, or other bare ground. Bury all carcasses found and any uneaten bait at the end of the program.

For broadcast applications, apply 4 to 6 pounds of prebait per acre (4.5 to 6.7 kg/ha) in 20-foot (6.1-m) swaths using hand- or ground-driven equipment. Two to 4 days later, apply an equal amount of treated bait in the same location. Special care must be taken to prevent application of treated bait over bare ground or in areas of scant vegetation, where it can pose a direct threat to grain-eating birds.

Fumigants should never be used in or around buildings, or where there is any danger that people, livestock, or other nontarget animals will come into contact with the gases. Treat and plug all burrows, wait 24 to 48 hours, and retreat any burrows that have been reopened. Repeat this process until all burrows stay closed. Most burrow fumigants work best when the soil moisture is high and the air temperature is above 50° F (10° C).

Aluminum phosphide tablets and pellets can be used to treat thirteen-lined ground squirrel burrows in agricultural and noncropland areas. Label recommendations are to place 1 to 4 tablets or 5 to 20 pellets as far down into the burrow as possible. The lower rates are recommended for smaller burrow systems under high moisture conditions, and the higher rates are recommended for larger burrow systems when soil moisture is low. Seal the burrow entrance by packing the opening with crumpled newspaper and then shoveling soil over the entrance. Be careful not to cover the tablets or pellets with soil when sealing the burrow. Several states have placed additional restrictions on the use of this material.

Gas cartridges that contain potassium nitrate or sodium nitrate work similarly and therefore will be described together. In the closed burrow system, a burning cartridge produces carbon monoxide (CO), carbon dioxide (CO_2), and consumes oxygen. To use a gas cartridge, prepare it according to label instructions. Cut a clump of sod slightly larger than the burrow opening with a spade or other suitable tool. Kneel at the burrow opening, light the fuse, and immediately place the cartridge, fuse end first, as far down the burrow as possible. Place the cartridge, do not throw it. Immediately place the sod, grass side down, over the opening and cover with soil to make a tight seal. Close any other openings from which smoke appears.

Gas cartridges come in different sizes. Therefore, make sure the cartridge will fit into the burrow before lighting the fuse. Some cartridges come with built-in fuses; others must have the fuse inserted by the operator. Check the specific product label for instructions and prepare the cartridge accordingly. Avoid prolonged breathing of the smoke when using gas cartridges, and do not use them near buildings or other combustible material because of the fire hazard.

Trapping

A few ground squirrels around a home garden or small row crop operation can be removed easily using wooden-base rat-sized snap traps, glue boards, or live traps. Snap traps and glue boards can kill animals caught in them. If it is necessary to restrict access to traps and glue boards by nontarget animals, place the traps under inverted wooden boxes with a 2-inch (5-cm) hole cut in each end. This will, however, reduce trapping success.

Wooden-base rat-sized snap traps are readily available and the easiest to use for most home gardeners. The biggest mistake most people make when trying to trap nuisance animals is not using enough traps. Set traps in the areas where damage is occurring, next to active burrows, or on active runways.

Peanut butter is one of the most effective baits and is difficult for the ground squirrel to remove without springing the trap. Pieces of apple or other fruit, vegetable, or nut meat, can also be used as bait. Securely attach these baits to the trap trigger. You can increase the attractiveness of most baits by scattering about 1/2 teaspoon of rolled oats on and around the trap. Cover the set, leaving enough room for proper operation of the trap. Check the traps every 24 hours and apply fresh bait. If more than 2 or 3 days go by without the trap being sprung, move the trap to a new location. If the bait is taken without the trap being sprung, try using mouse-sized snap traps. Young ground squirrels may not be big enough to spring the rat-sized trap.

Glue boards, either commercial or homemade, can be used to capture nuisance ground squirrels in residential areas. Place glue boards in areas where activity or damage is occurring. Bait them with the same type of material used to bait snap traps. Place bait in the center of the board. Once the animal becomes trapped, it can be killed and disposed of. Glue boards do not work well in dusty, dirty environments. Care should be taken when using glue boards outside because they can be attractive to children, pets, and nontarget wildlife.

Live traps are commercially available from a variety of manufacturers (see **Supplies and Materials** at the end of this manual), or they can be homemade. Use live traps that are 3 to 5 inches square and 18 to 20 inches long (8 to 13 cm square and 46 to 51 cm long). The 5 x 5 x 18-inch (13 x 13 x 46-cm) chipmunk-sized trap works well.

Burrow-entrance live traps can be constructed using 0.5-inch (1.3-cm) hardware cloth (Fig. 3). The main body of the trap is formed from a 12 x 20-inch (30 x 50-cm) piece bent to form a rectangular box 3 x 3 x 20 inches (8 x 8 x 51 cm). The joining edges can be secured with hog rings. Use hog rings to secure a 3-inch (8-cm) square piece of hardware cloth to one end of the trap. The trap door is made from a piece of hardware cloth 2 3/4 x 8 inches (7 x 20 cm). Attach one end of the door to the top of the trap with hog rings. Recess the point of attachment about 1 inch (2.5 cm) to permit free movement of the door when the trap is placed in the burrow entrance. Bend the opposite end of the door so at least 2 inches (5 cm) of the door are in contact with the trap floor when the door is closed. A wire handle should be attached to the top of the trap (Fig. 3).

Before setting the trap, spend some time observing the squirrels to determine which burrows are active. Set the

trap by wedging the door end firmly into the entrance of an active burrow. The closed end should be pointing into the air. Prop the trap in position with a block of wood or other suitable object. Gravity will hold the door closed until the squirrel pushes past it to leave its burrow and enters the trap. Dispose of trapped animals in accordance with local regulations.

Snares made of 8 pound (3.6 kg) test monofilament or wire fishing leader are simple and effective. Leghold traps (No. 0 longspring or coil-spring), and Conibear® traps (No. 110) can also be used. However, the effort required to set them, compared to snap traps, glue boards, and burrow-entrance live traps, makes their use questionable.

Shooting

Shooting can provide control if the landowner is willing to put in the necessary time and effort. All shooting should be carried out in a safe manner and in strict accordance with local regulations.

Other Methods

Ground squirrels were often captured by the Native Americans that lived on the central plains and the west coast by pouring water down the animal's burrow, thereby forcing the squirrel to the surface. Similar methods of removing ground squirrels still work. Flooding can enhance the effectiveness of trapping and snaring. Avoid flooding burrows that are adjacent to building foundations or other underground structures that may be damaged by water.

Economics of Damage and Control

The exact cost of damage caused by the thirteen-lined ground squirrel is difficult to quantify because much of it probably goes unreported. For the homeowner with one or two ground squirrels in the garden or a farmer with a few ground squirrels in the field, the animals may be more of a nuisance than a serious pest. However, when large numbers are present, they can cause serious losses. Thirteen-lined ground squirrels have established colonies in and around borders of minimum tillage corn fields in Nebraska. Extension agents and farmers there have reported losses of 20 to 80 acres (8 to 32 ha) annually in fields during 1989 to 1992.

Results of a survey of USDA-APHIS-ADC state offices, and of the Alberta, Manitoba, and Saskatchewan Provincial Wildlife Services, indicate that the thirteen-lined ground squirrel is only a minor pest in most suburban areas, and a minor to moderate pest in most agricultural situations. Indiana ADC considers them a major agricultural pest in no-till corn. As minimum tillage farming increases, the potential for increased agricultural damage from thirteen-lined ground squirrels may increase.

The most effective method of controlling thirteen-lined ground squirrel damage will depend on the situation and on the temperament of the people involved. Wooden-base rat-sized snap traps, live traps, or gas cartridges may be the best methods for eliminating one or two animals from a garden. Burrow fumigation may be the best method in truck gardens, or in and around parks, athletic fields, and cemeteries where the use of traps or poison could pose a hazard to people, pets, and nontarget wildlife. In orchards, vineyards and noncrop areas zinc phosphide treated baits may be most economical.

Acknowledgments

We thank Richard Dolbeer and Tom Seamans, USDA-APHIS-Denver Wildlife Research Center; Douglas Andrews, USDA-APHIS-ADC; and David Wolfert, USFWS for their editorial assistance in the preparation of this manuscript.

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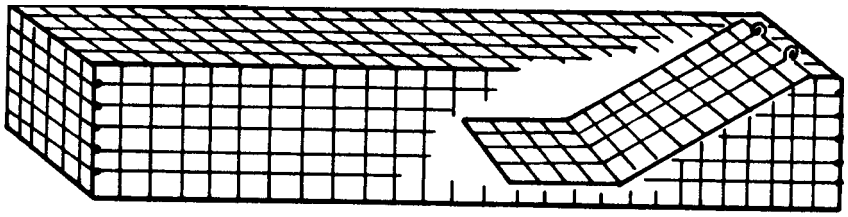


Fig. 3. Ground squirrels can be readily captured in this homemade live trap (Adapted from Wobeser and Leighton 1979).

Editors
Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Jeffrey J. Jackson
Extension Wildlife Specialist
Warnell School of Forest Resources
University of Georgia
Athens, Georgia 30602

TREE SQUIRRELS

Fig. 1. Fox squirrel, *Sciurus niger*

Damage Prevention and Control Methods

Exclusion

Install sheet metal bands on isolated trees to prevent damage to developing nuts.

Close external openings to buildings to stop damage to building interiors.

Place an 18-inch (46-cm) section of 4-inch (10-cm) diameter plastic pipe or a one-way door over openings to allow squirrels to leave and prevent them from returning.

Plastic tubes on wires may prevent access to buildings.

Cultural Methods

Remove selected trees or their branches to prevent access to structures.

Repellents

Naphthalene (moth balls), Ro-pel, capsaicin, and polybutenes are registered for controlling tree squirrels.

Toxicants

None are registered.

Fumigants

None are registered.

Trapping

Leghold traps.

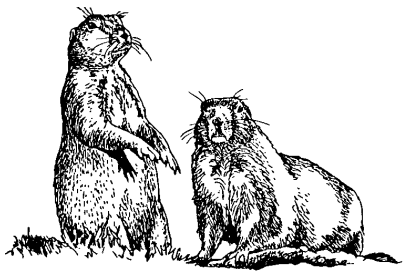
Box and cage traps.

Rat snap traps.

Box choker traps.

Shooting

Effective where firearms are permitted. Use a shotgun with No. 6 shot or a .22-caliber rifle.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

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B-171

Identification

In this chapter tree squirrels are divided into three groups: large tree squirrels, pine squirrels, and flying squirrels. Large tree squirrels include fox (*Sciurus niger*), eastern gray (*Sciurus carolinensis*), western gray (*Sciurus griseus*), and tassel-eared (*Sciurus aberti*) squirrels.

Fox squirrels (Fig. 1) measure 18 to 27 inches (46 to 69 cm) from nose to tip of tail. They weigh about 1 3/4 pounds (787 g) to 2 1/4 pounds (1,012 g). Color varies greatly, from all black in Florida to silver gray with a white belly in Maryland. Georgia fox squirrels usually have a black face. Ohio and Michigan fox squirrels are grizzled gray-brown above with an orange underside. Sometimes several color variations occur in a single population.

Eastern gray squirrels are also variable in color. Some have a distinct reddish cast to their gray coat. Black ones are common in some northern parts of their range. Eastern gray squirrels measure 16 to 20 inches (41 to 51 cm). They weigh from 1 1/4 pounds (567 g) to 1 3/4 pounds (794 g).

The western gray squirrel is gray above with sharply distinct white underparts. Size is similar to that of the eastern gray squirrel.

Tassel-eared squirrels are similar in size to gray squirrels and have several color phases. The most common is gray above with a broad reddish band down the back. Black tufted ears are their most distinguishing characteristic (the tufts are larger in winter, about 1 inch [2.5 cm]).

There are two species of pine squirrels: the red squirrel (*Tamiasciurus hudsonicus*) and Douglas pine squirrel (*Tamiasciurus douglasii*). Pine squirrels are 10 to 15 inches (25 to 38 cm) in total length and weigh 1/3 to 2/3 pounds (151 to 303 g). Red squirrels are red-brown above with white underparts. Douglas squirrels are gray-brown above with yellowish underparts. Both species have small ear tufts and often have a black stripe separating the dark upper color from the light belly.

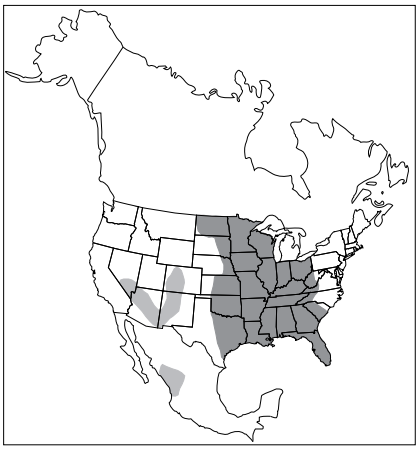

Fig. 2. Range of the fox squirrel (dark) and tassel-eared squirrel (light) in North America.

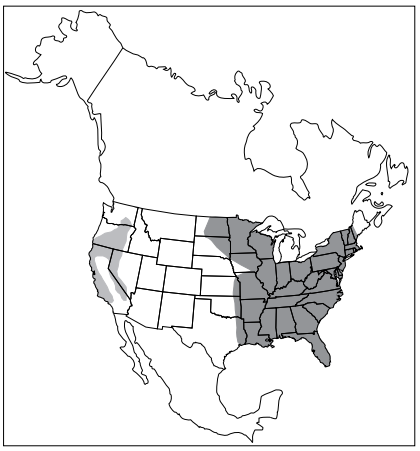

Fig. 3. Range of the eastern gray squirrel (dark) and western gray squirrel (light) in North America.

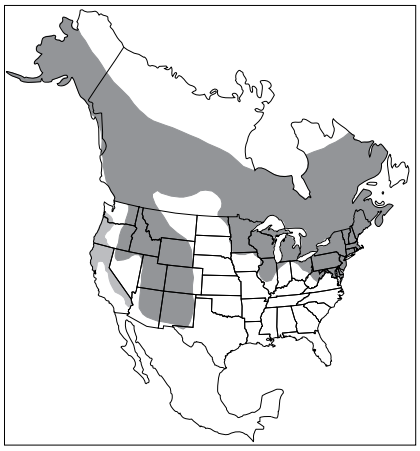

Fig. 4. Range of the red squirrel (dark) and Douglas squirrel (light) in North America.

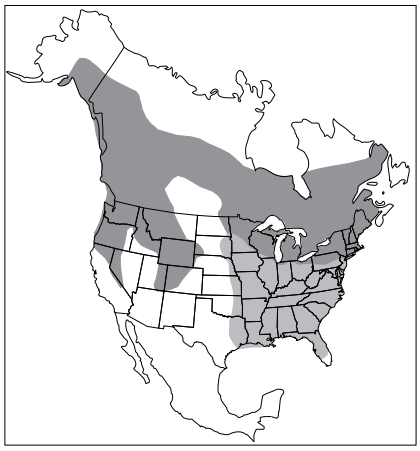

Fig. 5. Range of the northern flying squirrel (dark) and southern flying squirrel (light) in North America.

Two species of flying squirrels occur in North America. The southern flying squirrel (*Glaucomys volans*) is 8 to 10 inches (20 to 25 cm) long. The northern flying squirrel (*Glaucomys sabrinus*) averages 2 inches (5 cm) longer. It can be difficult to distinguish between the two; both may be various shades of gray or brown above and lighter below. A sharp line of demarcation separates the darker upper color from the lighter belly. The most distinctive characteristics of flying squirrels are the broad webs of skin connecting the fore and hind legs at the wrists, and the distinctly flattened tail.

Range

Fox squirrels occur in much of the eastern and central United States, as well as in several locations in the West, where they have been introduced (Fig. 2).

Eastern gray squirrels have a similar range to that of fox squirrels but do not occur in many western areas of the fox squirrel's range. They have been introduced in several locations in the West (Fig. 3).

Western gray squirrels are confined to west coast states and a small portion of western Nevada (Fig. 3).

Pine squirrels occur across northern North America south into the Appalachians and Rockies, and on the west coast.

Red squirrels are often associated with coniferous forests. The Douglas squirrel is restricted to the west coast from southwestern British Columbia south through the Sierras to northern Baja California (Fig. 4).

The tassel-eared squirrel is restricted to Ponderosa pine forests in the Southwest, usually at altitudes above 5,000 feet (1,500 m). It occurs in portions of Wyoming, Colorado, New Mexico, Arizona, and Utah (Fig. 2).

The northern flying squirrel occurs across northern North America. Its range extends south into the Appalachians and Rockies. The southern flying squirrel occurs in the central and eastern United States (Fig. 5).

Habitat

Fox squirrels and gray squirrels inhabit the same kinds of forests, both hardwood and coniferous, over much of their range. Gray squirrels are more abundant where a high percentage of land is forested. In areas with 10% forest cover, fox and gray squirrel populations may be equal. Fox squirrels prefer oak-hickory habitat over much of their range, especially in the West. In Georgia and Florida, fox squirrels seem to prefer pine timber. The western gray squirrel prefers mixed hardwoods and conifers and dry open hardwoods. Tassel-eared squirrels are strongly associated with Ponderosa pine. Pine squirrels prefer coniferous forests but also occur in mixed conifer and hardwood forests, or sometimes in hardwood habitats.

Food Habits

Fox and gray squirrels have similar food habits. They will eat a great variety of native foods and adapt quickly to unusual food sources. Typically, they feed on mast (wild tree fruits and nuts) in fall and early winter. Acorns, hickory nuts, walnuts, and osage orange fruits are favorite fall foods. Nuts are often cached for later use. In late winter and early spring they prefer tree buds. In summer they eat fruits, berries, and succulent plant materials. Fungi, corn, and cultivated fruits are taken when available. During population peaks, when food is scarce, these squirrels may chew bark from a variety of trees. They will also eat insects and other animal matter.

Pine squirrels are often heavily dependent on coniferous forests for cones and buds but will also eat a variety of other foods common to gray and fox squirrel diets. Douglas squirrels depend largely on Ponderosa pine for food. Flying squirrels' food habits are generally similar to those of other squirrels. However, they are the most carnivorous of all tree squirrels. They eat bird eggs and nestlings, insects, and other animal matter when available. Flying squirrels often occupy bird houses, especially bluebird houses.

General Biology, Reproduction, and Behavior

Fox and gray squirrels breed when they are 1 year old. They breed in mid-December or early January and again in June. Young squirrels may breed only once in their first year. The gestation period is 42 to 45 days.

During the breeding season, noisy mating chases take place when one or more males pursue a female through the trees.

They nest in tree cavities, human-made squirrel boxes, or in leaf nests. Leaf nests are constructed with a frame of sticks filled with dry leaves and lined with leaves, strips of bark, corn husks, or other materials. Survival of young in cavities is higher than in leaf nests. Cavities are the preferred nest sites.

About 3 young comprise a litter. At birth they are hairless, blind, and their ears are closed. Newborns weigh about 1/2 ounce (14 g) at birth and 3 to 4 ounces (84 to 112 g) at 5 weeks. Young begin to explore outside the nest about the time they are weaned at 10 to 12 weeks. At weaning they are about half of their adult weight.

Home range size depends on the season and availability of food. It may vary from 1 to 100 acres (0.4 to 40 ha). Squirrels move within their range according to availability of food. They often seek mast-bearing forests in fall and favor tender buds in elm and maple forests in the spring.

During fall, squirrels may travel 50 miles (80 km) or more in search of better habitat. Squirrel populations periodically rise and fall. During periods of high populations, squirrels—especially gray squirrels—may go on mass emigrations. At such times many animals die.

Fox and gray squirrels are vulnerable to numerous parasites and diseases. Ticks, mange mites, fleas, and internal parasites are common. Squirrel hunters often notice bot fly larvae (called "wolves" or "warbles") protruding from the skin. These fly larvae do not impair the quality of the meat for eating.

Squirrels are a food source for hawks, owls, snakes, and several mammalian predators. Predation seems to have little effect on squirrel populations.

Typically about half the squirrels in a population die each year. In the wild, squirrels over 4 years old are rare, while in captivity individuals may live 10 years or more.

The biology of other North American squirrels has much in common with that of fox and gray squirrels, although most other species have one breeding season per year. Flying squirrels are unique in that they are active at night. All other species are active during the day.

Damage

Squirrels may occasionally damage forest trees by chewing bark from branches and trunks. Pine squirrels damage Ponderosa pine, jack pine, and paper birch. In the Southeast, fox squirrels damage loblolly and other pines.

These species and others may eat cones and nip twigs to the extent that they interfere with natural reseeding of important forest trees. This is a particular problem in Ponderosa pine forests where pine squirrels may remove 60% to 80% of the cones in poor to fair seed years. In forest seed orchards, such squirrel damage interferes with commercial seed production.

In nut orchards, squirrels can severely curtail production by eating nuts prematurely and by carrying off mature nuts. In New England fruit orchards, pine squirrels may eat ovaries of cherry blossoms and destroy ripe pears. Pine, gray, and fox squirrels may chew bark of various orchard trees.

In residential areas, squirrels sometimes travel powerlines and short out transformers. They gnaw on wires, enter buildings, and build nests in attics. They frequently chew holes through pipelines used in maple syrup production.

Squirrels occasionally damage lawns by burying or searching for and digging up nuts. They will chew bark and clip twigs on ornamental trees or shrubbery planted in yards. Often squirrels take food at feeders intended for birds. Sometimes they chew to enlarge openings of bird houses and then enter to eat nestling songbirds. Flying squirrels are small enough to enter most bird houses and are especially likely to eat nesting birds.

In gardens, squirrels may eat planted seeds, mature fruits, or grains such as corn.

Legal Status

Fox and gray squirrels are usually classified as game animals in states where they occur. The tassel-eared squirrel is normally a protected species. Check with local or state authorities to determine legal status of squirrels in your area.

Damage Prevention and Control Methods

Exclusion

Prevent squirrels from climbing isolated trees and power poles by encircling them with a 2-foot-wide (61-cm) collar of metal 6 feet (1.8 m) off the ground. Attach metal using encircling wires held together with springs to allow for tree growth.

Prevent squirrels from traveling on wires by installing 2-foot (61-cm) sections of lightweight 2- to 3-inch diameter (5.1- to 7.6-cm) plastic pipe. Slit the pipe lengthwise, spread it open, and place it over the wire. The pipe will rotate on the wire and cause traveling squirrels to tumble.

Close openings to attics and other parts of buildings but make sure not to lock squirrels inside. They may cause a great deal of damage in their efforts to chew out. Place traps inside as a precaution after openings are closed. A squirrel excluder can be improvised by mounting an 18-inch (46-cm) section of 4-inch (10-cm) plastic pipe over an opening. The pipe should point down at a 45° angle. A one-way door can also be used over an opening to let squirrels out and prevent them from returning.

Close openings to buildings with heavy 1/2-inch (1.3-cm) wire mesh or make other suitable repairs.

Custom-designed wire mesh fences topped with electrified wires may effectively keep out squirrels out of gardens or small orchards.

Habitat Modification

Trim limbs and trees to 6 to 8 feet (1.8 to 2.4 m) away from buildings to prevent squirrels from jumping onto roofs.

In backyards where squirrels are causing problems at bird feeders, consider providing an alternative food source. Wire or nail an ear of corn to a tree or wooden fence post away from where the squirrels are causing problems.

In high-value crop situations, it may pay to remove woods or other trees near orchards to block the "squirrel highway."

Repellents

Naphthalene (moth balls) may temporarily discourage squirrels from entering attics and other enclosed spaces. Use of naphthalene in attics of occupied buildings is not recommended, however, because it can cause severe distress to people. Supplement this method with lights. A cat in the attic may discourage squirrels.

Ro-pel is a taste repellent that can be applied to seeds, bulbs, and flowers; trees and shrubs; poles and fences; siding and outdoor furniture. Capsaicin is also a taste repellent, registered for use on maple sap collecting equipment.

Polybutenes are sticky materials that can be applied to buildings, railings, downspouts, and other areas to keep squirrels from climbing. They can be messy. A preapplication of masking tape is recommended.

Toxicants

None are registered.

Fumigants

None are registered.

Trapping

A variety of traps will catch squirrels, including No. 0 or No. 1 leghold traps, the "Better Squirrel and Rat Trap," box traps, and cage traps. Regular rat-sized snap traps will catch flying squirrels and small pine squirrels. Glue traps for rats will catch small squirrels.

Since squirrels are classified as game species in most states, trapping permits may be required from your local state wildlife agency or municipal Animal Control office. Wire cage traps and box traps can be used to capture squirrels alive. Tie trap doors open for 2 to 3 days to get squirrels accustomed to feeding in the traps. Then set the traps and check them twice daily. Inform your neighbors of your trapping activities. Translocation of tree squirrels is a questionable practice because of the stress placed on transported and resident squirrels and concerns regarding the transmission of diseases.

Good baits are slices of orange and apple, walnuts or pecans removed from the shell, and peanut butter. Other foods familiar to the squirrel may also work well, such as corn or sunflower seeds.

Shooting

Where firearms are permitted, shooting is effective. A shotgun with No. 6 shot or a .22-caliber rifle is suitable. Check with your state wildlife agency for regulations pertaining to the species in your area.

Other Methods

Often several control methods used simultaneously are more successful than a single method. For example, to remove a squirrel from an attic, watch squirrels to determine where they enter. Then use repellents and lights to drive them out. After squirrels appear to have left the building, use appropriate exclusion methods to keep them out. One or more baited traps will catch squirrels that are accidentally closed in. This last step is very important because locked-in squirrels may cause damage when they try to chew their way out.

Squirrel damage in yards, gardens, forests, and orchards is often very difficult to control. During population highs, new squirrels arrive quickly to replace those shot or trapped.

Economics of Damage and Control

Squirrels cause economic losses to homeowners, nut growers, and forest managers. The extent of these losses is not well known.

Squirrels caused 177 power outages in Lincoln, Nebraska, in 1980, which was 24% of all outages. Estimated annual costs were $23,364 for repairs, public relations, and lost revenue. In Omaha, in 1985, squirrels caused 332 outages costing at least $47,144. After squirrel guards were installed over pole-mounted transformers in Lincoln in 1985, annual costs were reduced 78% to $5,148.

Acknowledgments

References by Boggess (1980) and Flyger and Gates (1982a,b) were particularly useful in preparing this publication. The manuscript was read and improved by the comments of Elizabeth McGhee.

Figure 1 from Schwartz and Schwartz (1981).

Figures 2 through 4 adapted from Flyger and Gates (1982a,b) by Jill Sack Johnson.

Figure 5 adapted from Burt and Grossenheider (1976) by David Thornhill.

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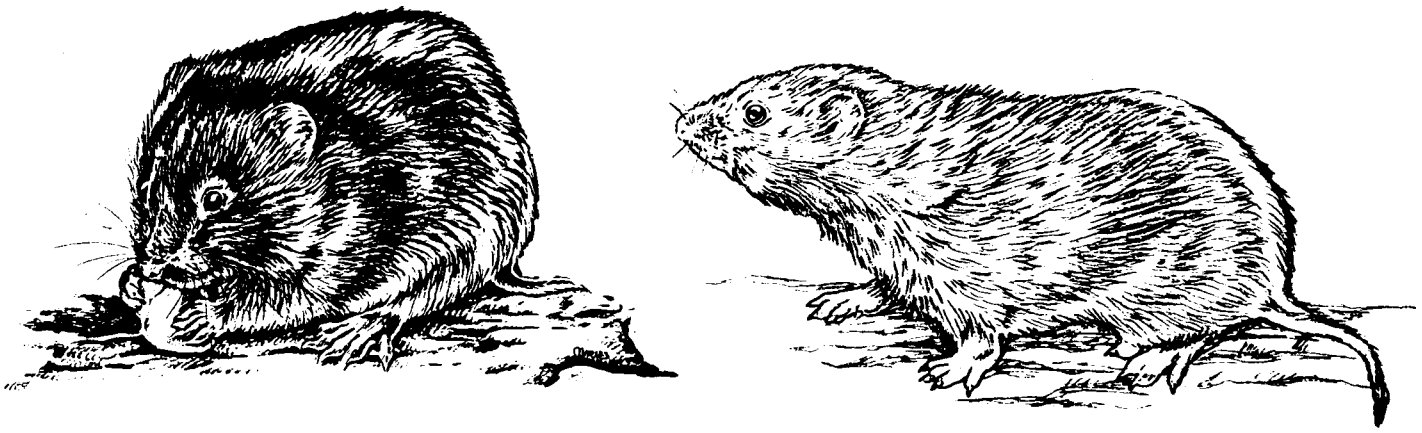
Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

John M. O'Brien
Agricultural Programs Coordinator
Nevada Department of Agriculture
Reno, Nevada 89510

VOLES

Fig. 1. Pine vole, *Microtus pinetorum* (left), and prairie vole, *M. ochrogaster* (right).



Damage Prevention and Control Methods

Exclusion

Recommended to protect trees, ornamental plants, and small areas.

Habitat Modification

Eliminating ground cover reduces populations.

Soil cultivation destroys burrows and reduces cover.

Frightening

Not effective.

Repellents

Effectiveness uncertain.

Toxicants

Zinc phosphide.

Anticoagulants (registered in most states).

Fumigants

Not usually effective.

Trapping

Mouse snap traps.

Live traps (Sherman or box-type traps).

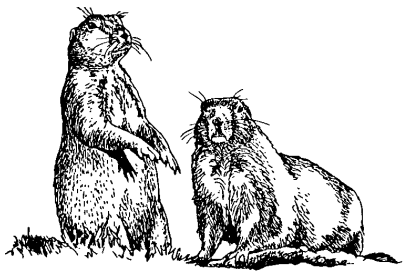
Shooting

Not practical or effective.

Identification

Voles, also called meadow mice or field mice, belong to the genus *Microtus.* Voles are compact rodents with stocky bodies, short legs, and short tails. Their eyes are small and their ears partially hidden. Their underfur is generally dense and covered with thicker, longer guard hairs. They usually are brown or gray, though many color variations exist.

There are 23 vole species in the United States. This chapter provides range maps, descriptions, and habitat characteristics for seven species that are widespread or cause significant economic damage. Tentative identification of a particular animal may be made using this information. For positive identification, use a field guide or contact an expert.



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B-177

Prairie Vole (*Microtus ochrogaster*). The prairie vole is 5 to 7 inches (13 to 18 cm) in total length (nose to tip of tail). Its fur is gray to dark brown and mixed with gray, yellow, or hazel-tipped hairs, giving it a "peppery" appearance. Underparts are gray to yellow-gray. It is the most common vole in prairie habitats.

Meadow Vole (*M. pennsylvanicus*). The meadow vole is the most widely distributed *Microtus* species in the United States. Its total length is 5 1/2 to 7 1/2 inches (14 to 19 cm) and its fur is gray to yellow-brown, obscured by black-tipped hairs. Northern subspecies may also have some red in their fur. Its underparts are gray, at times washed with silver or buff. The tail is bicolored.

Long-tailed Vole (*M. longicaudus*). The long-tailed vole can be distinguished from other *Microtus* species by its tail, which comprises 30% or more of its total length of 6 to 8 1/2 inches (15 to 21 cm). The long-tailed vole has gray to dark brown fur with many black-tipped hairs. The underparts are gray mixed with some white or yellow. The tail is indistinctly to sharply bicolored.

Pine or Woodland Vole (*M. pinetorum*). The pine vole is a small vole. Its total length is 4 to 6 inches (10 to 15 cm). Its brown fur is soft and dense. The underparts are gray mixed with some yellow to cinnamon. The tail is barely bicolored or unicolored.

Montane (or Mountain) Vole (*M. montanus*). The montane vole is 5 1/2 to 8 1/2 inches (15 to 20 cm) in total length. Its fur is brown, washed with gray or yellow, and mixed with some black-tipped hairs. Its feet are usually silver-gray and its body underparts are whitish. The tail is bicolored.

Oregon Vole (*M. oregoni*). The Oregon vole is 5 1/2 to 6 1/2 inches (14 to 16 cm) in length. Its fur is gray to brown or yellow-brown. Underparts are darkish, washed with yellow to white. The tail is indistinctly bicolored.

California Vole (*M. californicus*). The California vole is 6 to 8 1/2 inches (15 to 20 cm) in total length. Its fur is tawny olive to cinnamon brown with brown to black overhairs. The underparts are grayish. The tail is bicolored.

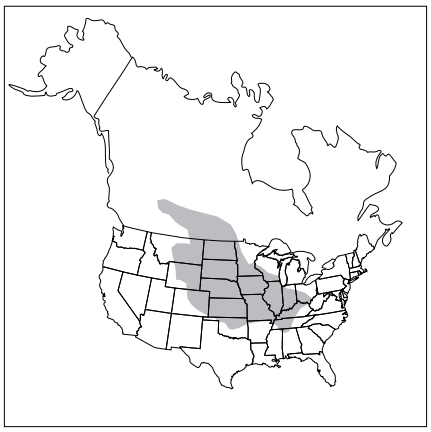

Fig. 2. Distribution of the prairie vole in North America.

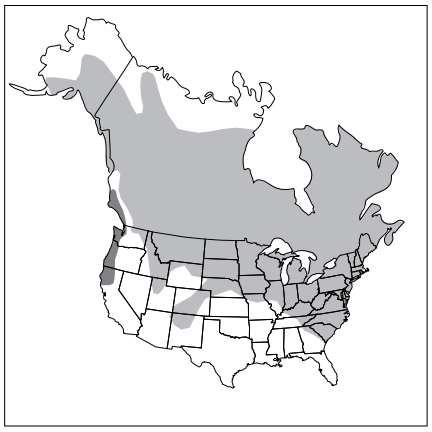

Fig. 3. Distribution of the meadow (light) and California voles (dark) in North America.

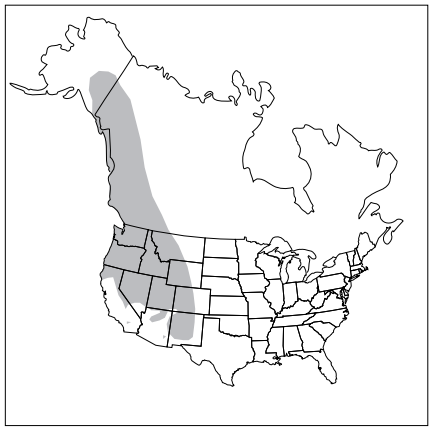

Fig. 4. Distribution of the long-tailed vole in North America.

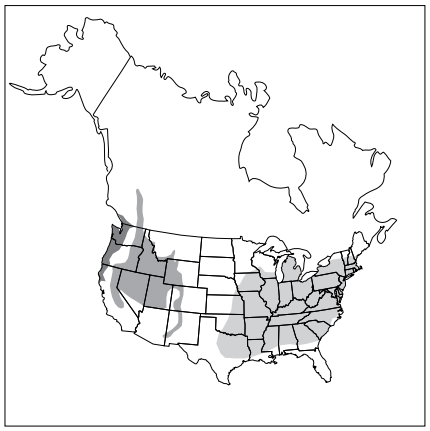

Fig. 5. Distribution of the pine (light), montane (medium), and Oregon voles (dark) in North America.

Range

Figures 2, 3, 4, and 5 show the approximate ranges of these species.

Habitat

Voles occupy a wide variety of habitats. They prefer areas with heavy ground cover of grasses, grasslike plants, or litter. When two species are found together in an area, they usually occupy different habitats. Though voles evolved in "natural" habitats, they also use habitats modified by humans, such as orchards, windbreaks, and cultivated fields, especially when vole populations are high. Characteristic habitat descriptions for the seven described species follow.

Prairie Vole. The prairie vole, as the name suggests, is the most common vole of the Great Plains grasslands. It is found in a variety of habitats, such as old fields, marshlands, and grass prairies. When in association with the meadow vole, it is generally in drier habitats.

Meadow Vole. The meadow vole is found in the northern United States and Canada. It prefers wet meadows and grassland habitats. When in association with the montane vole or prairie vole, it is generally in moister habitats.

Long-tailed Vole. The long-tailed vole is found in a wide variety of habitats (for example, sagebrush grasslands, forests, mountain meadows, and stream banks) in the western United States and Canada.

Pine Vole. The pine vole is found in the eastern United States. It inhabits a variety of habitats such as deciduous and pine forests, abandoned fields, and orchards. Heavy ground cover is characteristic of these habitats.

Montane Vole. The montane vole is found primarily in mountainous regions of the western United States. It is found in alpine meadows, dry grasslands, and sagebrush grasslands. It avoids forests. When in association with the meadow vole, it is generally in drier habitats.

Oregon Vole. The Oregon vole is most often found in forested areas of northern California, Oregon, and Washington where there is an understory of forbs and grasses such as in burned or clear-cut areas.

California Vole. The California vole inhabits the chaparral woodland shrubland of California. It is found in both wet and well-drained areas.

Food Habits

Voles eat a wide variety of plants, most frequently grasses and forbs. In late summer and fall, they store seeds, tubers, bulbs, and rhizomes. They eat bark at times, primarily in fall and winter, and will eat crops, especially when their populations are high. Occasional food items include snails, insects, and animal remains.

General Biology, Reproduction, and Behavior

Voles are active day and night, year-round. They do not hibernate. Home range is usually 1/4 acre (0.1 ha) or less but varies with season, population density, habitat, food supply, and other factors. Voles are semifossorial and construct many tunnels and surface runways with numerous burrow entrances. A single burrow system may contain several adults and young.

Voles may breed throughout the year, but most commonly in spring and summer. In the field, they have 1 to 5 litters per year. They have produced up to 17 litters per year in a laboratory. Litter sizes range from 1 to 11, but usually average 3 to 6. The gestation period is about 21 days. Young are weaned by the time they are 21 days old, and females mature in 35 to 40 days. Lifespans are short, probably ranging from 2 to 16 months. In one population, there was 88% mortality during the first month of life.

Large population fluctuations are characteristic of voles. Population levels generally peak every 2 to 5 years; however, these cycles are not predictable. Occasionally during population irruptions, extremely high vole densities are reached. Dispersal, food quality, climate, predation, physiological stress, and genetics have been shown to influence population levels. Other factors probably also play a part.

Population densities are variable. Smolen and Keller (1987) list densities of long-tailed vole populations. A California population ranged from about 2 to 7 voles per acre (5 to 16/ha) and a New Mexico population ranged from around 8 to 49 voles per acre (20 to 121/ha). Cole and Batzli (1979) found that prairie vole populations averaged 15 per acre (38/ha) in prairie, 52 per acre (128/ha) in bluegrass, and 99 per acre (244/ha) in alfalfa. Another vole population ranged from 1 to 14 per acre (2 to 35/ha) over 3 years in western mixed prairie. Variability in meadow vole population density was reported by Taitt and Krebs (1985). An Ontario, Canada population ranged from 32 to 162 per acre (80 to 400/ha) over 1 year while an Illinois population ranged from 2 to 6 per acre (5 to 15/ha) also over 1 year. Other populations show similar year-to-year variability. Much higher densities may be reached during population irruptions. In Klamath Basin, Oregon, montane vole densities ranged from 200 to 500 per acre (500 to 1,250/ha) and may have reached 4,000 per acre (10,000/ha) in some instances during a 1957 to 1958 irruption.

Many voles are excellent swimmers. The water vole, in fact, escapes predators by swimming and diving. The climbing ability of voles varies. The long-tailed vole, for example, is a good climber (Johnson and Johnson 1982) while the pine vole is a bit clumsy in this regard.

Voles are prey for many predators (for example, coyotes, snakes, hawks, owls, and weasels); however, predators do not normally control vole populations.

Damage and Damage Identification

Voles may cause extensive damage to orchards, ornamentals, and tree plantings due to their girdling of seedlings and mature trees. Girdling damage usually occurs in fall and winter. Field crops (for example, alfalfa, clover, grain, potatoes, and sugar beets) may be damaged or completely destroyed by voles. Voles eat crops and also damage them when they build extensive runway and tunnel systems. These systems interfere with crop irrigation by displacing water and causing levees and checks to wash out. Voles also can ruin lawns, golf courses, and ground covers.

Girdling and gnaw marks alone are not necessarily indicative of the presence of voles, since other animals, such as rabbits, may cause similar damage. Vole girdling can be differentiated from girdling by other animals by the non-uniform gnaw marks. They occur at various angles and in irregular patches. Marks are about 1/8 inch (0.3 cm) wide, 3/8 inch (1.0 cm) long, and 1/16 inch (0.2 cm) or more deep. Rabbit gnaw marks are larger and not distinct. Rabbits neatly clip branches with oblique clean cuts. Examine girdling damage and accompanying signs (feces, tracks, and burrow systems) to identify the animal causing the damage.

The most easily identifiable sign of voles is an extensive surface runway system with numerous burrow

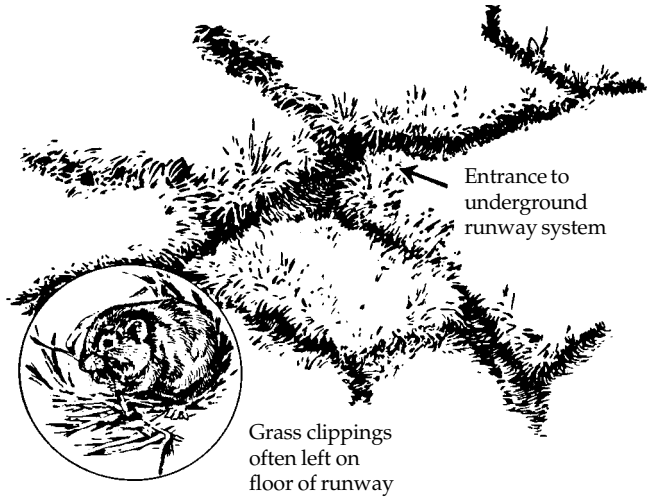

Fig. 6. Surface runway system of the prairie vole.

opening (Fig. 6). Runways are 1 to 2 inches (2.5 to 5 cm) in width. Vegetation near well-traveled runways may be clipped close to the ground. Feces and small pieces of vegetation are found in the runways.

The pine vole does not use surface runways. It builds an extensive system of underground tunnels. The surface runways of long-tailed voles are not as extensive as those of most other voles.

Voles pose no major public health hazard because of their infrequent contact with humans; however, they are capable of carrying disease organisms, such as plague (*Yersinia pestis*) and tularemia (*Francisilla tularensis*). Be careful and use protective clothing when handling voles.

Legal Status

Voles are classified as nongame mammals and can be controlled when causing damage. Contact your local state wildlife agency for details regarding applicable codes and regulations.

Damage Prevention and Control Methods

Exclusion

Hardware cloth cylinders exclude voles from seedlings and young trees. The mesh should be 1/4 inch (0.6 cm) or less in size. Bury the wire 6 inches (15 cm) to keep voles from burrowing under the cylinder. Large scale fencing of areas is probably not cost-effective. Drift fences with pit traps may be used to monitor populations and can indicate when voles are immigrating to crops, orchards, or other cultivated areas.

Cultural Methods and Habitat Modification

Cultural and habitat modification practices can reduce the likelihood and severity of vole damage. Eliminate weeds, ground cover, and litter in and around crops, lawns, and cultivated areas to reduce the capacity of these areas to support voles. Lawn and turf should be mowed regularly. Mulch should be cleared 3 feet (1 m) or more from the bases of trees.

Voles can live in dense populations in ditch banks, rights-of-way, and water ways that are unmanaged. Adjacent crop fields can be cost-effectively protected by controlling vegetation through mowing, spraying, or grazing.

Soil tillage is effective in reducing vole damage as it removes cover, destroys existing runway-burrow systems and kills some voles outright. Because of tillage, annual crops tend to have lower vole population levels than perennial crops. Voles are nevertheless capable of invading and damaging annual crops, especially those that provide them with cover for extended periods of time.

Frightening

Frightening agents are not effective in reducing vole damage.

Repellents

Repellents utilizing thiram (also a fungicide) or capsaicin (the "hot" in chilis) as an active ingredient are registered for meadow voles (see **Supplies and Materials**). These products (or repellents registered for other species) may afford short-term protection, but this has not been demonstrated. Check with your state pesticide regulatory agency for availability.

Toxicants

Zinc phosphide is the most commonly used toxicant for vole control. It is a single-dose toxicant available in pelleted and grain bait formulations and as a concentrate. Zinc phosphide baits generally are broadcast at rates of 6 to 10 pounds per acre (7 to 11 kg/ha), or are placed by hand in runways and burrow openings. Although prebaiting (application of similar nontreated bait prior to applying toxic bait) is not usually needed to obtain good control, it may be required in some situations, such as when a population has been baited several times and bait shyness has developed. Zinc phosphide baits are potentially hazardous to ground-feeding birds, especially waterfowl. Placing bait into burrow openings may reduce this hazard.

Anticoagulant baits are also effective in controlling voles. Anticoagulants are slow-acting toxicants requiring from 5 to 15 days to take effect. Multiple feedings are needed for most anticoagulants to be effective. In many states, one or more anticoagulant baits are registered for controlling voles.

In addition to broadcast and hand placement, anticoagulant baits also can be placed in various types of bait containers (Byers and Merson 1982, Radvanyi 1980). Water repellent paper tubes with an anticoagulant bait glued to the inside surface make effective, disposable bait containers. Tube size is about 5 inches (12 cm) long by 1 1/2 inches (4 cm) in diameter (Libby and Abrams 1966, Marsh et al. 1967). Bait

containers protect bait from moisture and reduce the likelihood of nontarget animals and small children consuming bait.

Fumigants

Fumigants usually are not effective because the complexity and shallowness of vole burrow systems allow the fumigant to escape. They may work in new, small burrow systems with only one or two entrances.

Trapping

Trapping is not effective in controlling large vole populations because time and labor costs are prohibitive. Mouse snap traps can be used to control a small population by placing the trap perpendicular to the runway with the trigger end in the runway. A peanut butter-oatmeal mixture or apple slices make good baits. Fall and late winter are periods when many vole species are easiest to trap.

Although voles rarely invade houses, in the event that they do, they can be controlled by setting snap traps or live traps (Sherman or box-type) as you would for house mice (see Trapping in the **House Mice** chapter).

Shooting

Shooting is not practical or effective in controlling voles.

Other Methods

A wide variety of predators feed on voles. Voles are relatively easy for most predators to catch and are active, and therefore available, day and night year-round. Despite their vulnerability and availability, voles are not usually "controlled" by predators. This is because voles have a high reproductive potential. Postpartum breeding is common and females may breed as early as 2 weeks of age. Synchronous breeding also occurs. These factors enable voles to increase at a faster rate than predators (Pearson 1985).

Economics of Damage and Control

Jameson (1958) calculated that 100 meadow voles per acre destroyed about 4% of an alfalfa crop, which amounted to about 1,000 pounds per acre (1,136 kg/ha) over 7 months.

Populations of 1,700 voles per acre (4,250 voles/ha) in Washington State apple orchards decreased production by 35%. This amounted to a loss of $3,036 per acre ($7,590/ha) due to reduced fruit quality and quantity. One year after eliminating voles, the production in the orchard increased but was still below the production of orchards that had not incurred vole damage. Total losses for the 2-year period were estimated at $6,100 per acre ($15,250/ha) (Askham 1988). Similar apple orchard loss figures were calculated for pine voles in New York. Known densities of voles (0, 109, 218, and 436 per acre [0, 273, 545, and 1,090/ha]) were stocked in fenced blocks of McIntosh trees for 2 years. There was little impact the first year. The second year, the highest vole population reduced fruit yield 65.5% and increased undersized fruit from 3.1% to 57.5%. These factors caused a $2,745 per acre ($6,863/ha) reduction in income. In addition, survival of the trees through a third year was considered unlikely. The worst vole outbreak in the United States probably occurred in Nevada in 1908 and 1909. Ten thousand acres (400 ha) of alfalfa were completely destroyed. Vole populations were estimated at 25,000 per acre (62,500/ha).

Often a control program may not appear to be justified in comparison to the damage being incurred. It should be remembered, however, that the "ounce of prevention" rule frequently applies in vertebrate pest control. Preventive control measures that at first appear too costly may eventually prove to be a bargain.

Acknowledgments

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Figures 1 and 5 from Schwartz and Schwartz (1981).

Figures 2 through 4 adapted from Johnson and Johnson (1982) by Dave Thornhill, University of Nebraska-Lincoln.

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson

Rene M. Bollengier, Jr.
Assistant Regional Director (retired)
USDA-APHIS-
Animal Damage Control
Concord, New Hampshire 03302-2398

WOODCHUCKS

Fig. 1. Woodchuck, *Marmota monax*

Damage Prevention and Control Methods

Exclusion

Buried welded or woven wire fences.

Single-strand electric fences.

Frightening Devices

Scarecrows and other effigies.

Repellents

None are registered.

Toxicants

None are registered.

Fumigants

Gas cartridges.

Aluminum phosphide.

Trapping

Live traps.

No. 2 leghold traps.

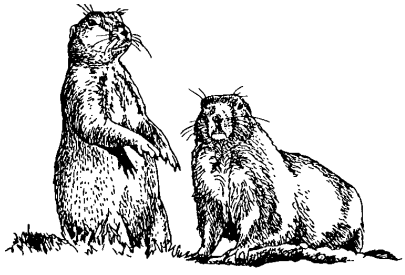
Conibear® traps.

Shooting

Effective where legal and safe.

Identification

The woodchuck (*Marmota monax*, Fig. 1), a member of the squirrel family, is also known as the "ground hog" or "whistle pig." It is closely related to other species of North American marmots. It is usually grizzled brownish gray, but white (albino) and black (melanistic) individuals can occasionally be found. The woodchuck's compact, chunky body is supported by short strong legs. Its forefeet have long, curved claws that are well adapted for digging burrows. Its tail is short, well furred, and dark brown.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

B-183

Both sexes are similar in appearance, but the male is slightly larger, weighing an average of 5 to 10 pounds (2.2 to 4.5 kg). The total length of the head and body averages 16 to 20 inches (40 to 51 cm). The tail is usually 4 to 7 inches (10 to 18 cm) long. Like other rodents, woodchucks have white or yellowish-white, chisel-like incisor teeth. Their eyes, ears, and nose are located toward the top of the head, which allows them to remain concealed in their burrows while they check for danger over the rim or edge. Although they are slow runners, woodchucks are alert and scurry quickly to their dens when they sense danger.

Range

Woodchucks occur throughout eastern and central Alaska, British Columbia, and most of southern Canada. Their range in the United States extends throughout the East, northern Idaho, northeastern North Dakota, southeastern Nebraska, eastern Kansas, and northeastern Oklahoma, as well as south to Virginia and northern Alabama (Fig. 2).

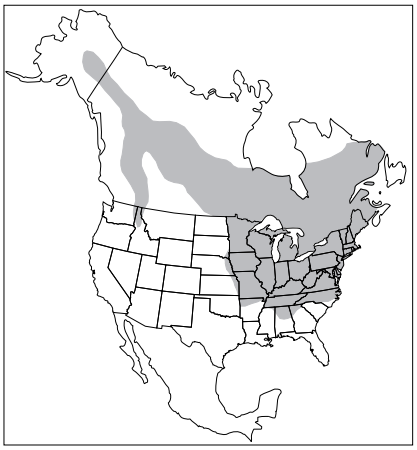


Fig. 2. Range of the woodchuck in North America.

Habitat

In general, woodchucks prefer open farmland and the surrounding wooded or brushy areas adjacent to open land. Burrows commonly are located in fields and pastures, along fence rows, stone walls, roadsides, and near building foundations or the bases of trees. Burrows are almost always found in or near open, grassy meadows or fields. Woodchuck burrows are distinguished by a large mound of excavated earth at the main entrance. The main opening is approximately 10 to 12 inches (25 to 30 cm) in diameter. There are two or more entrances to each burrow system. Some secondary entrances are dug from below the ground and do not have mounds of earth beside them. They are usually well hidden and sometimes difficult to locate (Fig. 3). During spring, active burrows can be located by the freshly excavated earth at the main entrance. The burrow system serves as home to the woodchuck for mating, weaning young, hibernating in winter, and protection when threatened.

Food Habits

Woodchucks prefer to feed in the early morning and evening hours. They are strict herbivores and feed on a variety of vegetables, grasses, and legumes. Preferred foods include soybeans, beans, peas, carrot tops, alfalfa, clover, and grasses.

General Biology, Reproduction, and Behavior

Woodchucks are primarily active during daylight hours. When not feeding, they sometimes bask in the sun during the warmest periods of the day. They have been observed dozing on fence posts, stone walls, large rocks, and fallen logs close to the burrow entrance. Woodchucks are good climbers and sometimes are seen in lower tree branches.

Woodchucks are among the few mammals that enter into true hibernation. Hibernation generally starts in late fall, near the end of October or early November, but varies with latitude. It continues until late February and March. In northern latitudes, torpor can start earlier and end later. Males usually come out of hibernation before females and subadults.

Males may travel long distances, and occasionally at night, in search of a mate. Woodchucks breed in March and April. A single litter of 2 to 6 (usually 4) young is produced each season after a gestation period of about 32 days. The young are born blind and hairless. They are weaned by late June or early July, and soon after strike out on their own. They frequently occupy abandoned dens or burrows. The numerous new burrows that appear during late summer are generally dug

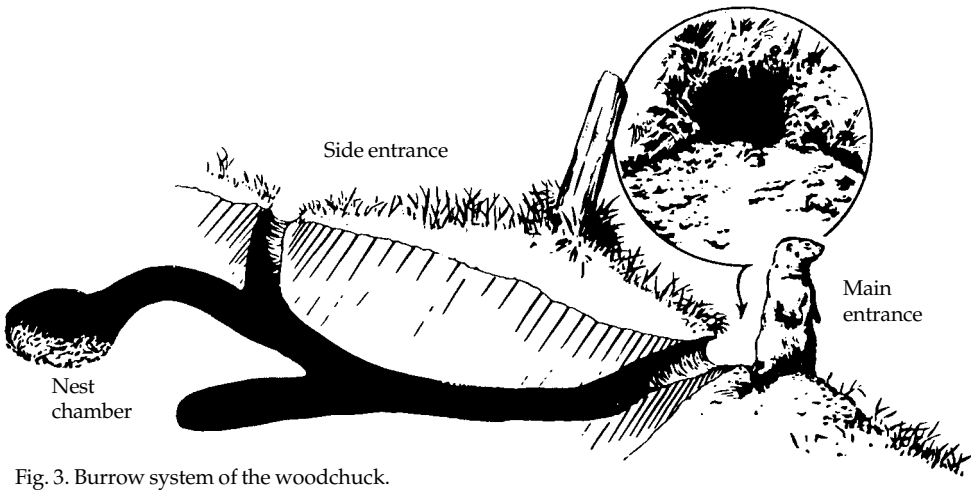


Fig. 3. Burrow system of the woodchuck.

by older woodchucks. The life span of a woodchuck is about 3 to 6 years.

Woodchucks usually range only 50 to 150 feet (15 to 30 m) from their den during the daytime. This distance may vary, however, during the mating season or based on the availability of food. Woodchucks maintain sanitary den sites and burrow systems, replacing nest materials frequently. A burrow and den system is often used for several seasons. The tunnel system is irregular and may be extensive in size. Burrows may be as deep as 5 feet (1.5 m) and range from 8 to 66 feet (2.4 to 19.8 m) in total length (Fig. 3). Old burrows not in use by woodchucks provide cover for rabbits, weasels, and other wildlife.

When startled, a woodchuck may emit a shrill whistle or alarm, preceded by a low, abrupt "phew." This is followed by a low, rapid warble that sounds like "tchuck, tchuck." The call is usually made when the animal is startled at the entrance of the burrow. The primary predators of woodchucks include hawks, owls, foxes, coyotes, bobcats, weasels, dogs, and humans. Many woodchucks are killed on roads by automobiles.

Damage

On occasion, the woodchuck's feeding and burrowing habits conflict with human interests. Damage often occurs on farms, in home gardens, orchards, nurseries, around buildings, and sometimes around dikes. Damage to crops such as alfalfa, soybeans, beans, squash, and peas can be costly and extensive. Fruit trees and ornamental shrubs are damaged by woodchucks as they gnaw or claw woody vegetation. Gnawing on underground power cables has caused electrical outages. Damage to rubber hoses in vehicles, such as those used for vacuum and fuel lines, has also been documented. Mounds of earth from the excavated burrow systems and holes formed at burrow entrances present a hazard to farm equipment, horses, and riders. On occasion, burrowing can weaken dikes and foundations.

Legal Status

In most states, woodchucks are considered game animals. There is usually no bag limit or closed season. In damage situations, woodchucks are usually not protected. The status may vary from state to state, depending on the control technique to be employed. Consult with your state wildlife department, USDA-APHIS-Animal Damage Control representative, or extension agent before shooting and/or trapping problem individuals.

Damage Prevention and Control Methods

Exclusion

Fencing can help reduce woodchuck damage. Woodchucks, however, are good climbers and can easily scale wire fences if precautions are not taken. Fences should be at least 3 feet (1 m) high and made of heavy poultry wire or 2-inch (5-cm) mesh woven wire. To prevent burrowing under the fence, bury the lower edge 10 to 12 inches (25 to 30 cm) in the ground or bend the lower edge at an L-shaped angle leading outward and bury it in the ground 1 to 2 inches (2.5 to 5 cm). Fences should extend 3 to 4 feet (0.9 to 1.2 m) above the ground. Place an electric wire 4 to 5 inches (10 to 13 cm) off the ground and the same distance outside the fence. When connected to a UL-approved fence charger, the electric wire will prevent climbing and burrowing. Bending the top 15 inches (38 cm) of wire fence outward at a 45° angle will also prevent climbing over the fence. Fencing is most useful in protecting home gardens and has the added advantage of keeping rabbits, dogs, cats, and other animals out of the garden area. In some instances, an electric wire alone, placed 4 to 5 inches (10 to 13 cm) above the ground, has deterred woodchucks from entering gardens. Vegetation in the vicinity of any electric fence should be removed regularly to prevent the system from shorting out.

Frightening Devices

Scarecrows and other effigies can provide temporary relief from woodchuck damage. Move them regularly and incorporate a high level of human activity in the susceptible area.

Repellents

None are registered.

Toxicants

None are registered for woodchuck control.

Fumigants

Gas cartridge (carbon monoxide). The most common means of woodchuck control is the use of commercial gas cartridges. They are specially designed cardboard cylinders filled with slow-burning chemicals. They are ignited and placed in burrow systems, and all entrances are sealed. As the gas cartridges burn, they produce carbon monoxide and other gases that are lethal to woodchucks. Gas cartridges are a General Use Pesticide and are available from local farm supply stores, certain USDA-APHIS-ADC state and district offices, and the USDA-APHIS-ADC Pocatello Supply Depot. Directions for their use are on the label and should be carefully read and closely followed (see information on gas cartridges in the **Pesticides** and **Supplies and Materials** sections).

Be careful when using gas cartridges. Do not use them in burrows located under wooden sheds, buildings, or near other combustible materials because of the potential fire hazard. Gas cartridges are ignited by lighting a fuse. They will not explode if properly prepared and used. Caution should be taken to avoid prolonged breathing of fumes.

Each burrow system should be treated in the following manner:

1. Locate the main burrow opening (identified by a mound of excavated soil) and all other secondary entrances associated with that burrow system.

2. With a spade, cut a clump of sod slightly larger than each opening. Place a piece of sod over each entrance except the main entrance. Leave a precut sod clump next to the main entrance for later use.
3. Prepare the gas cartridge for ignition and placement following the written instructions on the label.
4. Kneel at the main burrow opening, light the fuse, and immediately place (do not throw) the cartridge as far down the hole as possible.
5. Immediately after positioning the ignited cartridge in the burrow, close the main opening or all openings, if necessary, by placing the pieces of precut sod, grass side down, over the opening. Placing the sod with the grass side down prevents smothering the lit cartridge. Make a tight seal by packing loose soil over the piece of sod. Look carefully for smoke leaking from the burrow system and cover or reseal any openings that leak.
6. Continue to observe the site for 4 to 5 minutes and watch nearby holes. Continue to reseal those from which smoke is escaping.
7. Repeat these steps until all burrow systems have been treated in problem areas.

Burrows can be treated with gas cartridges at any time. This method is most effective in the spring before the young emerge. On occasion, treated burrows will be reopened by another animal reoccupying the burrow system. If this occurs, retreatment may be necessary.

Aluminum Phosphide. Aluminum phosphide is a Restricted Use Pesticide and can be applied only by a certified pesticide applicator. Treatment of burrow systems is relatively easy. Place two to four tablets deep into the main burrow. Plug the burrow openings with crumpled newspapers and then pack the openings with loose soil. All burrows must be sealed tightly but avoid covering the tablets with soil. The treatment site should be inspected 24 to 48 hours later and opened burrows should be retreated.

Aluminum phosphide in the presence of moisture in the burrow produces hydrogen phosphide (phosphine) gas. Therefore, soil moisture and a tightly sealed burrow system are important. The tablets are presently approved for outdoor use on noncropland and orchards for burrowing rodents. Tablets should not be used within 15 feet (5 m) of any occupied building or structure or where gases could escape into areas occupied by other animals or humans. Storage of unused tablets is critical — they must be kept in their original container, in a cool, dry, locked, and ventilated room. They must be protected from moisture, open flames, and heat.

The legal application and use of aluminum phosphide for woodchuck control may vary from state to state. Check with your state pesticide registration board, USDA-APHIS-ADC representative, or extension agent when considering use of this material. Aluminum phosphide should always be applied as directed on the label.

Trapping

Steel leghold and live traps. Traps may also be used to reduce woodchuck damage, especially in or near buildings. Both steel leghold and live traps are effective. Trapping should be used in areas where gas cartridges or aluminum phosphide may create a fire hazard or where fumes may enter areas to be protected. Woodchucks are strong animals and a No. 2 steel trap is needed to hold them. Before using steel traps, consult your state wildlife department or USDA-APHIS-ADC representative for trapping regulations. Steel traps should not be employed in areas where there is a possibility of capturing pets or livestock.

Live trapping can sometimes be difficult, but is effective. Live traps can be built at home, purchased from commercial sources (see **Supplies and Materials**), or borrowed. Bait traps with apple slices or vegetables such as carrots and lettuce, and change baits daily. Locate traps at main entrances or major travel lanes. Place guide logs on either side of the path between the burrow opening and the trap to help funnel the animal into the trap. Check all traps twice daily, morning and evening, so that captured animals may be quickly removed. A captured animal can be relocated to an area with suitable habitat where no additional damage can be caused. The animal can also be euthanized by lethal injection (by a veterinarian or under veterinarian supervision), by shooting, or by carbon dioxide gas.

Conibear® traps. Conibear® traps are effective in some situations. A set in a travelway, such as between a wood pile and barn, can be very effective. Sets can also be made at the main entrance of the burrow system. Logs, sticks, stones, and boards should be used to block travelways around the set and/or to lead the animal into the set. No bait is necessary for Conibear® sets. Conibear® 110s, 160s, and 220s are best suited for woodchuck control. Conibears® are well suited for use near or under structures in which fumigants and shooting present a hazard. Conibear® 110s will handle young, small animals, while 160s and 220s will also handle larger adults.

Conibear® traps kill the animal quickly and care should be taken to avoid trapping domestic animals such as cats and dogs. Some state or local laws prohibit the use of Conibear® traps except in water. Consult your state wildlife department or USDA-APHIS-ADC office for regulations.

Shooting

In many states, woodchucks are considered game animals. Therefore, if shooting is permitted, a valid state hunting license may be required. In some states there is no closed season, nor is there usually any limit on the number of woodchucks that can be taken by hunters. If shooting can be accomplished safely, landowners and/or hunters can reduce or maintain a low population of woodchucks where necessary. Landowners and hunters should agree on hunting arrangements prior to initiating any shooting activities. Another alternative

would be to have a professional USDA-APHIS-ADC representative do the job. He or she will be familiar with legalities and techniques. Contracting with a Animal Damage Control professional would be especially valuable when and where large numbers of woodchucks are causing serious economic losses. Shooting can be used as a follow-up to other, more substantial control activities.

Rifles with telescopic sights are commonly used in the sport shooting of woodchucks. A variety of calibers can be used, but .22-caliber centerfire rifles are most popular. Occasionally, shotguns are used to eliminate woodchucks that are causing damage. The objective is to remove the animal as humanely as possible without wounding it. Shotgun gauge, range, and shot size should be considered when using this method. Use a 12-gauge with No. 4 to No. 6 shot. The range should be within 25 yards (23 m).

Carefully assess the area behind and around the target for safety. Pellets can ricochet, causing injury or serious damage in background areas. Use of a rifle or shotgun should be conducted only if good shooting conditions exist.

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Figures 1 through 3 from Schwartz and Schwartz (1981), adapted by Jill Sack Johnson.

For Additional Information

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Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson