

University of Nebraska - Lincoln

DigitalCommons@University of Nebraska - Lincoln

---

The Handbook: Prevention and Control of Wildlife  
Damage

Wildlife Damage Management, Internet Center for

---

7-27-1994

## Belding's, California, and Rock Ground Squirrels

Rex E. Marsh

*University of California, Davis*

---

Marsh, Rex E., "Belding's, California, and Rock Ground Squirrels" (1994). *The Handbook: Prevention and Control of Wildlife Damage*.  
Paper 26.

<http://digitalcommons.unl.edu/icwdmhandbook/26>

This Article is brought to you for free and open access by the Wildlife Damage Management, Internet Center for at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in The Handbook: Prevention and Control of Wildlife Damage by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

**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

## 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.*

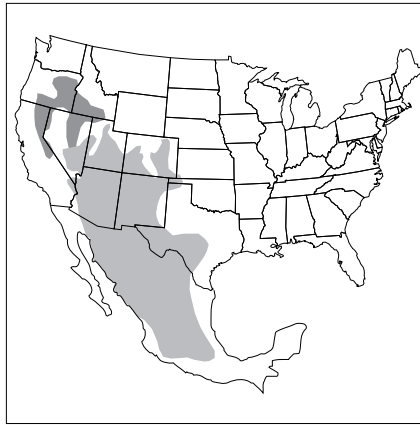


Fig. 3. Range of the Belding's (dark) and rock ground squirrels (light) in North America.



Fig. 4. Range of the California ground squirrel in North America.

*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.

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<sup>2</sup>) 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.

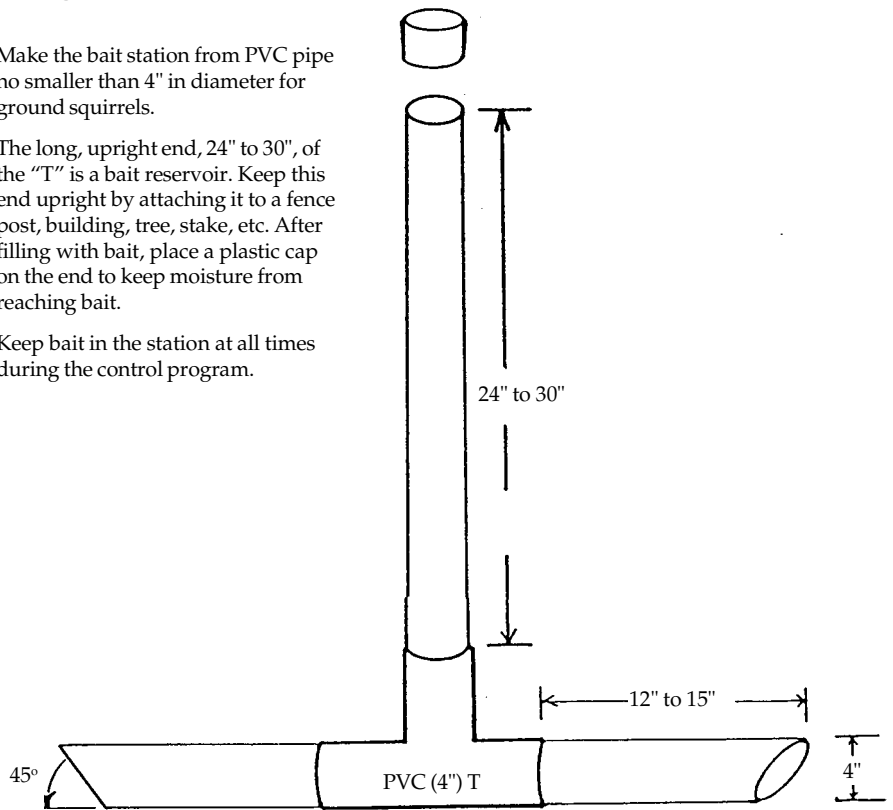


Fig. 5. Commonly used inverted "T" ground squirrel bait station made of 4-inch (10-cm) PVC pipe. Stake secures station in upright position.

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.

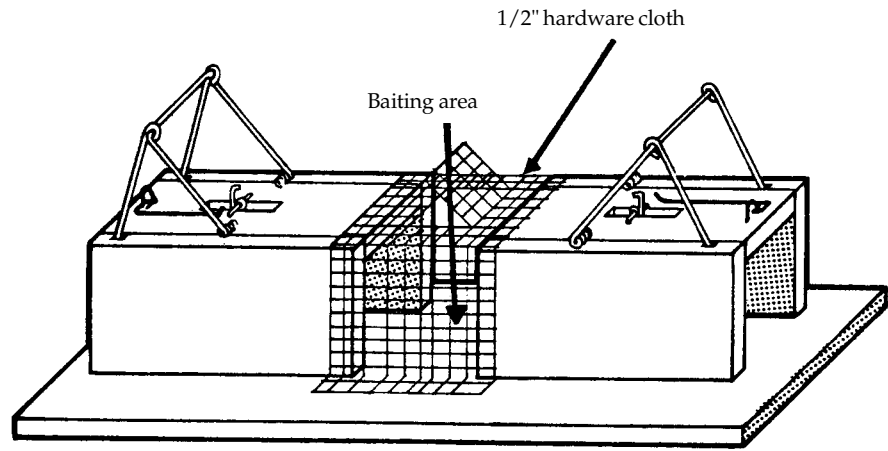
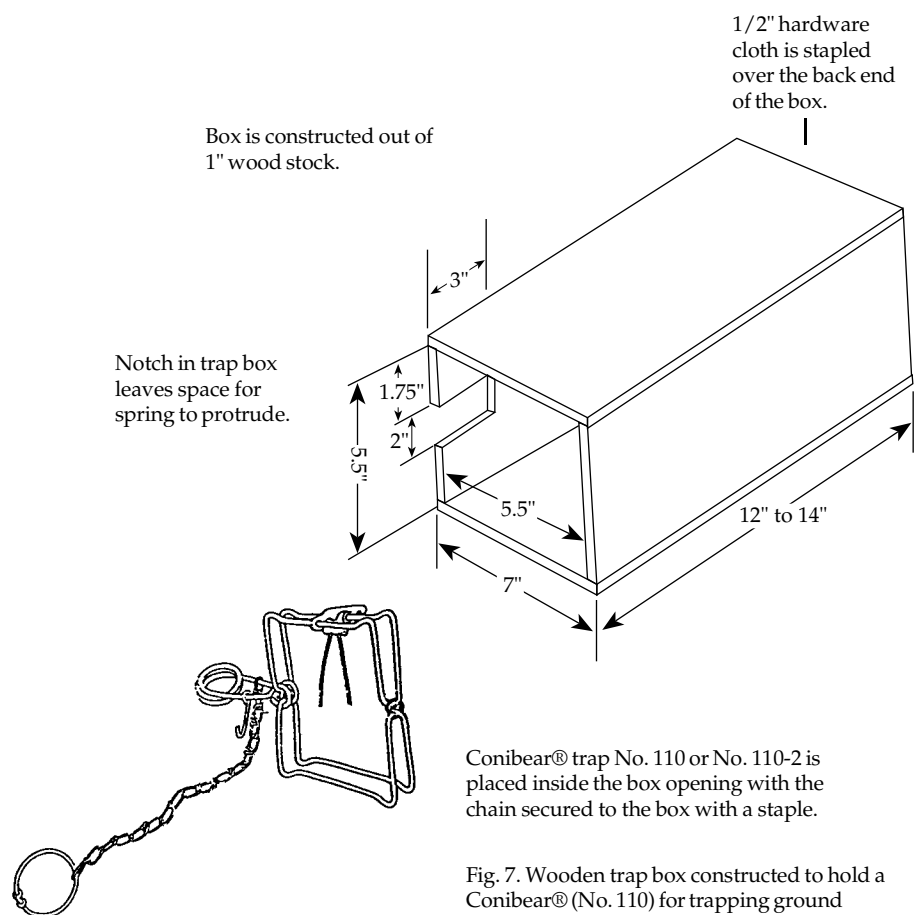


Fig. 6. Two modified pocket gopher traps mounted on a single board with a common bait area are very effective for trapping ground squirrels.



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

Beard, M. L., G. O. Maupin, A. M. Barnes, and E. F. Marshall. 1987. Laboratory trials of cholecalciferol against *Spermophilus variegatus* (rock squirrels), a source of human plague (*Yersinia pestis*) in the southwestern United States. *J. Environ. Health* 50:287-289.

Clark, J. P. 1986. Vertebrate pest control handbook (rev.). Div. Plant Industry, California Dep. Food Agric., Sacramento, California. 350 pp.

Hall, E. R. 1981. The mammals of North America. Vol. 1, 2d ed. John Wiley and Sons, New York. 600 pp.

Marsh, R. E. 1987. Ground squirrel control strategies in California agriculture. Pages 261-276 in C. G. J. Richards and T. Y. Ku, eds. Control of mammal pests. Taylor & Francis, London.

Salmon, T. P. 1981. Controlling ground squirrels around structures, gardens, and small farms. Div. Agric. Sci., Univ. California, Leaflet 21179. 11 pp.

Salmon, T. P., and R. H. Schmidt. 1984. An introductory overview to California ground squirrel control. *Proc. Vertebr. Pest Conf.* 11:32-37.

Tomich, P. Q. 1982. Ground squirrels. Pages 192-208 in J. A. Chapman and G. A. Feldhamer, eds. Wild mammals of North America: biology, management, and economics. The Johns Hopkins Univ. Press, Baltimore, Maryland.

## Editors

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