2-6-1962

GROUND SQUIRREL CONTROL IN CALIFORNIA

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The control of ground squirrels in California is important in two ways. First, it is necessary to prevent destruction of agricultural crops. Second, it is important from a health standpoint where rodent-borne diseases have been demonstrated to be present. Ground squirrel control in this State is the responsibility of the county agricultural commissioners, the State Department of Agriculture and on Federal lands the Bureau of Sport Fisheries and Wildlife. Most control measures are concerned with but two of the nine species of ground squirrels found in California. These include four subspecies: Beechey ground squirrel (Citellus beecheyi beecheyi), Douglas ground squirrel (Citellus beecheyi douglasii), Fisher ground squirrel (Citellus beecheyi fisheri), and Oregon ground squirrel (Citellus oregonus).

The more aggressive species, the Beecheyi ground squirrel, is found along coastal California from the Golden Gate and Carquinez Straits south nearly to San Diego; the Fisher ground squirrel inhabits the greater part of central California east of the Feather and Sacramento Rivers south to the southern end of the San Joaquin Valley.

The Douglas ground squirrel occurs northward from San Francisco Bay throughout the region west and north of the Sacramento and Feather Rivers extending north to the Oregon line. The smaller short-tailed Oregon ground squirrel inhabits the northeastern plateau counties of Modoc, Lassen, Siskiyou and Plumas.

Ground squirrels have enormous "comeback" powers. So long as an adequate food supply is available, their annual litters will average

about 6 to 8 young; therefore, a few years of neglect by the growers may create new centers of population which, will reinfest clean areas.

A natural habit characteristic of Beechey ground squirrels is hibernation. The squirrels go through non-specific periods of dormancy in the winter months, and during certain periods of drought and extremely hot weather they go through a period of aestivation, or "summer sleep", all of which complicates control procedure. Too often after control measures have been applied, ground squirrels later appear on the treated area because some had been dormant at the time control was done.

There are several essential steps to consider before control is undertaken. The arbitrary selection of a grain bait is not satisfactory. Field test plots using several kinds of clean bait must be put out in small piles on bare ground to determine bait preference. The piles of bait should not be placed in or directly in front of the burrows. The selection of the grain bait to be used is made only after exposure of two or more kinds of untreated grain.

It is also necessary to determine the period of maximum squirrel activity if optimum results are to be achieved. One period of high activity occurs during the breeding season. To accurately define this period, which varies with geographic and climatic conditions as well as with species, it is necessary to shoot a number of squirrels to determine sex ratio. As the breeding period nears, the ratio of males to females tends to equalize, and this is considered by some authorities as the period of maximum activity. Prior to this period, males will predominate and, when the sex ratio is mostly males, it is too early to start control operations. Shooting or trapping is continued into the

period during which embryo counts can be made* From these examinations of the embryo, it is possible to fix with reasonable accuracy the time the work roust be curtailed as well as determining when it may be resumed.

The next step is to conduct bait acceptance tests to make sure the squirrels continue to take the preferred bait after it has been treated with a toxicant. For this purpose a pre-determined area on which the approximate number of squirrels is known is selected. The area must be a new one to avoid testing with squirrels that have been prebaited as a result of the bait preference tests. In no case is the same area used for both purposes. In acceptance tests the bait is scattered in the same manner as is done in normal control procedure. If bait acceptance is satisfactory and resulting kill is determined to be satisfactory, control measures should be started immediately.

The amount of treated bait used is highly important from an economic as well as conservation standpoint. A residue of about 10 per cent of the original bait following a 2^-hour exposure period is a good yardstick. Underbaiting results in poor control, whereas overbaiting creates unnecessary hazards. Once less than satisfactory results are duplicated it may be necessary to allow a rest period during which no grain baits are used.

The ultimate success of any rodent control program is entirely dependent on the effort expended by the person in charge of the job. It is essential that all phases of field work be carefully observed so that any changes in daily rodent activity, bait acceptance and degree of kill will be noted. The comprehension of these factors will result in a high

degree of efficiency and ultimately a more effective and economical control program.

POISON BAITS

1080. It is common practice with sodium fluoroacetate (lO8o), which has proven to be the most effective toxicant for the control of ground squirrels, to treat where possible only once every two or three years to maintain a continuously reduced population. This infrequent baiting is desirable as too frequent application of bait may bring about bait and poison shyness.

There is generally a period of four to six weeks during the breeding season when excellent results may be obtained. Control operations carried on during the breeding season are occasionally hampered due to work stoppage when unfavorable weather conditions occur.

Control work must be stopped as soon as the young become old enough to survive without adults and should not be resumed until the young appear above ground and are large enough to take bait. Then there should be no further interruptions until inspection determines a slowdown of activity indicating aestivation. This normally can be expected following a few days of hot weather. Aestivation may continue on into the winter hibernation in some areas. These dormant periods may be continuous or interrupted with different individuals. In some areas there may be a brief period of high activity in October and November when effective control measures may be applied.

Most rodenticides are toxic to wildlife if ingested in sufficient amounts. Protection of birds has been achieved by coloring grain baits and using feed grains that birds tend to reject. Modification of the natural kernel shape serves to make the grain less attractive to birds.

These deterrents, together with good judgment in timing, do much to hold accidental mortality among birds to a minimum. The use of 1080 and Thallium sulfate in California is restricted to qualified persons according to law. Section IO8O.5 and 1080.6 of the California Agricultural Code is the authority.

Some times there is a marked difference in effectiveness of a poison with different sub-species. For example, the Douglas ground squirrel of northern California is easy to control with strychnine> while in the area south of San Francisco Bay the closely related Beechey ground squirrel is difficult to control with strychnine baits.

Strychnine. The success of poisoning with strychnine-coated grain is due largely to a squirrel's habit of gathering seeds and carrying them home in its cheek pouches during the dry season. The cheek pouches are muscular sacs within the mouth, each large enough to hold about 200 kernels of barley. Much of the food carried in the cheek pouches is not eaten at the time, but taken for winter use to underground storehouses or cached near the burrow entrance. When grain coated with a properly prepared strychnine solution is carried in the pouches, enough of the poison is dissolved and absorbed to quickly kill the animal. In 1909, S. E. Piper of the United States Bureau of Biological Survey made the important discovery that strychnine is far more quickly absorbed by the cheek pouches than by the stomach; he found that one-fifth the quantity necessary to kill by the stomach will kill when taken into the pouches (Merrlam, 1910). The rapidity in which the coated grain takes effect is demonstrated by the large percentage of squirrels that are overcome by the poison while still engaged in gathering the scattered kernels and

die before entering their burrows.

After the start of the rainy season when natural green feeds become available to squirrels, pouching ceases and strychnine grain is no longer effective. This led to recognition of the necessity to find some other poison which would be effective at this time of the year. During the green feed period, it may be necessary to use a stomach poison such as 1080 or thallium since the squirrels will not normally be pouching. This is one exception to this as occasionally Douglas squirrels will continue pouching baits after green feed has appeared.

Thallium Sulfate. In 1926, thallium sulfate was introduced from Europe (Piper and Jacobsen, *1944).* "This material was first used extensively in California against field rodents after trials proved it to be effective during late fall, winter and spring months as a relatively economical stomach poison and a suitable supplement to the strychnine coated grain method." Thallium sulfate is used on potted barley, crushed oats and squirrel oat groats.

Thallium sulfate is taken up during the normal digestive process. It is non-bitter in taste and is slow acting. If a good dose is ingested on the first feeding, the squirrel may be killed in a comparatively short time. However, if only a minimum lethal dose is taken, it may take several days for death to occur.

Zinc Phosphide. This material was investigated for ground squirrel control during the early 1940's. New techniques were attempted for causing this chemical to adhere to a variety of baits and it showed up surprisingly well in spite of earlier failures when freshly mixed, applied sparingly and used in rotation with other baits. Zinc phosphide is a poison which may kill within thirty minutes, or may allow the

animals to survive for several days. It may be used over a longer period than strychnine. It is usually applied on squirrel oat groats, crimped oats or whole barley.

Field observations have revealed that squirrels not consuming toxic grain baits would not eat clean grain of any kind. Clean grain has been given at different seasons of the year with the same results. Fortunately the percentage of animals thus rejecting grain is not large. The manner of feeding is also in the animal's favor. Some squirrels feed a little on one food, then on another. Generally, they do not sit by any one particular bait and fill up on it.

To overcome the problem of an aversion to bait or sub-lethal feeding in Oregon ground squirrels, White (1959) demonstrated in Modoc County that control could be achieved by mechanical baiting with a mixture of clean and toxic kernels. Treatments of 3 pounds per acre composed of 30 percent toxic grain (treated at concentrations of 5 ounces 1080 per 100 pounds of squirrel oat groats) and mixed with 70 percent clean whole oats gave a higher degree of control than conventional baiting methods employing no clean grain.

Anticoagulants. Anticoagulants have been used in many areas within the State where other rodenticides were considered too hazardous. The exposure of anticoagulant baits is generally done in bait boxes, although some areas are treated by the open bait exposure method. Both methods have resulted in satisfactory control but labor costs are high.

FUMIGAHTS

Carbon Bisulphide. Dr. E. W. Hilgard of the University of California Experiment Station in 1876 first advised the use of carbon

bisulphide upon ground squirrels after he had noted that it had been successfully used in France to exterminate rats in sewers.

The types of treatment used included the "waste ball" method, which is still being used in some areas. This method consists of saturating 50 to 60 jute balls (about 2 inches in diameter) in a bucket with a gallon of carbon bisulphide. One ball is thrown deep into each burrow. Immediately after a burrow is treated, the entrance should be closed with a shovelful of earth and quickly trampled to insure air tight sealing.

Another method in the use of carbon bisulphide consists of exploding the gas in the burrow. Carbon bisulphide is extremely inflammable and very explosive and therefore should be used with caution. The common procedure is to place a saturated waste ball in the burrow, seal the entrance with a piece of sod or a loose clod of earth for five to fifteen minutes to allow the gas to vaporize, then remove the clod, and apply a small lighted torch consisting of a cloth soaked in kerosene wrapped around a thin piece of pipe. The explosion will be extremely vigorous and has the advantage of indicating whether all the entrances of the burrows have been previously closed. This method should never be employed when the grass is dry as serious fires could result. Also extreme care should be used when lighting the gas in the burrow. This procedure of firing the burrows is often used in orchards with no detrimental effects on the trees.

The first practical pump to vaporize carbon bisulphide In squirrel burrows was developed by Surgeon J. D. Long of the United States Public Health Service. Several types of pumps have been used to force carbon vapors into squirrel burrows. In recent years the Demon Rodent Gun, a heavy metal cylinder with pump and reservoir for liquid carbon

bisulphide, has replaced practically all other types. The pump forces the carbon through a flexible hose and a spray nozzle. The nozzle is placed in the burrow, and the burrow mouth plugged with a shovelful of earth to prevent loss of gas. One stroke of the pump releases one fluid ounce of the carbon bisulphide, most of which will vaporize inside the burrow. After the hose has been withdrawn, the burrow entrance is immediately sealed with dirt or sod in sufficient quantity to make a little mound which should be well tramped and packed to prevent any escape of gas. The treated areas are usually rechecked within a week. All open burrows should be retreated with 2 to *h* ounces of carbon bisulphide.

Complex runways and pockets in burrows, the hibernation of squirrels and the isolation of females are the causes of some of the difficulties attending the use of gas. Another factor that makes the use of gas difficult is the squirrel's habit of "plugging" against an enemy. This simply means the squirrel will plug part of the runway and block off the exit. Squirrels do this against a gas invasion as well as animal enemies. Gases of low toxicity that diffuse slowly through the burrow, such as carbon dioxide and sulphur dioxide, have not proven successful. Carbon monoxide is effective, but so far no practical method of application has been devised. Carbon bisulphide applied with the waste-ball method has been quite effective, but there are disadvantages too. For example, it is limited to the wet season; it is slow to convert into a gaseous state, slow to diffuse throughout the burrow and has a slow physiological effect on the animal. All these factors considerably reduce its efficiency. The Demon Rodent Gun has removed some of these objections as it vaporizes the carbon bisulphide in a gaseous state, thereby quickly raising the concentration to a lethal level and preventing
the squirrel from escaping so easily.

The general use of carbon bisulphide has been limited to the wet season when the soil is well packed*and free of cracks so that the gas will remain in a lethal concentration for a longer time. This is necessary to ensure a kill as the animal must be in the gas several minutes unless it is at a very high concentration. Stewart and Burd (1918) reported that in a two percent concentration of carbon bisulphide a squirrel partially collapsed in from six to ten minutes and in seventeen to twenty minutes had ceased breathing.

Methyl Bromide. This material has proved to be effective in the control of rodents as well as the insects harbored by them. There is no danger from fire and it can be used in wet or dry soils and at various temperatures. Although the cost is higher than some of the other fumigants, it can be used where follow-up or eradication measures are being carried on and in areas where inflammables or toxic baits are undesirable.

Berry (193$) reported successful results in killing ground squirrels by injecting 10 cc methyl bromide per burrow. The use of one pound cans of methyl bromide and attachable dispensers has replaced many of the larger containers formerly used in ground squirrel control.

A one pound can contains 262 cc's of liquid methyl bromide. Theoretically it should deliver 26 10-cc dosages, but through repeated field use 17 to 20 dosages per pound appear to be average output per can.

Other Fumigants. A common method of controlling small infestations of ground squirrels is the use of the exhaust of an automobile. One end of a hose may be attached to the exhaust pipe and the other end inserted in the burrow. Stewart and Burd (1918) reported "carbon monoxide is

poisonous to both animals and human beings if as much as one-tenth of one percent is present in air". The carbon monoxide gas generated by the engine penetrates the burrow and will kill the squirrel quickly. This method is often used in orchards for cleanup work or where only a few ground squirrels remain.

Many fumigants have been tested to find a gas that would be fatal more quickly and at low concentrations. It is also necessary for the gas to be safe to handle with reasonable precautions. Some .of the many fumigants which have been tried are hydrocyanic acid gas, calcium cyanide, fumes of sulphur, gasoline, petroleum distillate, chloropicrin, kerosene and tetrachloroethane, some with varying success, but none have come into general use.

TRAPPING

Traps securely tied may be used at any season of the year to remove small local populations of squirrels, or to clean up those that escape poison or gas. The wooden box type gopher trap with certain modifications has been very effective in situations where other control methods are unsuitable.

Traps baited with an English walnut or piece of orange placed near the burrow entrance or tied to limbs of trees have been used successfully, even on fox squirrels. One modification is to replace the back of the trap with two 1 -inch strips of strap iron stapled to the two sides equal distance between the top of trap and the ground level. A piece of ½-inch hardware cloth will also suffice to cover the back. This lights up the interior of the box compartment and allows the bait to be observed from both ends, but still prevents the animal from entering the trap except from the front. Half of the trigger loop is

removed, and the bottom of the loop is straightened so that bait is held above the ground level. The trigger holding the spring on top of the trap is modified to release when pulled forward toward the trap front, live catch traps, consisting of a rectangular cage of hardware cloth with a drop door at either end and central trigger pan in the floor, are extremely effective in catching squirrels. Wire trap 6" x 6" x 19" is the recommended size for catching squirrels.

In trapping squirrels where there are a number to be taken, it is recommended that traps be set with the door open for a few days in the' areas where the squirrels are causing annoyance. The trap can be baited with almonds, walnuts, grain or other bait attractive to squirrels. In the course of a few days, all the squirrels will become completely used to the trap and will pass in and out freely. Then, when the doors are untied, one is able to take squirrels which might otherwise have a tendency to avoid the device.

The steel Jump trap No. 0 or 1 placed unbaited and buried flush with the surface near a feeding place or in the burrow entrance is a trapping procedure which has been used for many years. Baiting with this method is done by scattering grain over the traps.

SUMMARY

Poisoning, trapping and fumigating are the only known procedures offering any satisfactory solution to ground squirrel control and, of these, poisoning is usually the best method. Sodium fluoroacetate is the*most effective toxicant. Others that have been tried with varied success include strychnine, thallium, zinc phosphide and anticoagulants. The use of carbon bisulphide and methyl bromide as fumigants has proven successful. Contrary to opinion held by some, it is possible with

present knowledge of the characteristics of poisons and the habits of animals to select, prepare and expose baits so as not to seriously endanger other forms of wildlife and domestic animals.

BAIT FORMULAS

For Beechey, Fisher and Douglas Ground Squirrels

Sodium Fluoroacetate (1080) Formula

Whole Oats (recleaned)	100 pounds
Lecithin-mineral oil (22 ozs. liquid)	2/3 quart
Water	1 quart
Dye (Auramine 0 Cone. 130%)	½ ounce
Compound 1080 (Sodium fluoroacetate *90%)*	1 ounce

Heat the water and add the 1080; stir until dissolved; add the dye and stir; then add the lecithin-mineral oil and stir until you have an emulsion. (Do not boil.) Pour this mixture over bait and mix thoroughly. If bait is to be used in a reasonable time, it can be sacked without drying.

Squirrel oat groats may be used in place of whole oats.

Strychnine Formula

Whole Barley (recleaned)	100 pounds
Strychnine (powdered alkaloid)	5 ounces
Bicarbonate of soda (baking soda)	5 ounces
Saccharin	½ ounce
Heavy corn sirup	20 ounces
Thin starch paste	60 ounces
Glycerin	*2 ½* ounces

Mix thoroughly the powdered strychnine (alkaloid), baking soda and saccharin. Crush all lumps of the soda with mixing spoon. To this add corn sirup and stir thoroughly to a smooth, creamy paste free from lumps. Over this pour thin hot starch paste and stir well. (The starch

paste is made by dissolving the dry gloss starch in a little cold water which is then added to the boiling water. Boil and stir constantly until a clear thin paste is formed.) Add glycerin and stir thoroughly, making sure that none of the heavy sirup paste still sticks to the bottom of the container. Pour this mixture over the barley and mix well so that each grain is coated.

For making small quantities an ordinary galvanized wash tub is convenient. For larger quantities a mechanical mixer may be used.

A quart of the poisoned grain is sufficient for *40* to 50 baits. This quantity scattered along squirrel trails or on clean, hard places on the surface about the holes will not endanger stock.

N. B,—Strychnine in any form other than the powdered strychnine alkaloid is not effective in the above formula.

Thallium Sulphate Formula No. 1

Special steam-rolled oats	75 lbs.
Thallium sulphate (preferably ball milled)	1 lb.
Gloss or corn starch	10 ozs.
Glycerin	1 Tbs.
Water (hot)	6 qts.

Procedure same as for thallium formula No. 3»

The thallium sulphate is slowly dissolved in the hot water. This amount of water of ordinary purity will dissolve this amount of thallium. Where much impurity is present in the water, it sometimes requires as much as eight quarts of water to dissolve this amount of thallium. In some cases 100 pounds of oats to 1 pound of thallium sulphate have been used, and in cases where acceptance was rapid the results were apparently the same, which reduced the expense for bait

material.

Thallium Sulphate Formula No.2

Oat groats (semi crushed)	100 pounds
Water	1 quart
Lecithin-mineral oil	3/4 quart
Thallium sulfate (200 mesh) (Thallous sulfate 99%)	16 ounces

Mix water on bait first; then mix thallium in the lecithin mineral oil and pour over grain and mix thoroughly.

Thallium Sulphate Formula No. 3

Thallium sulphate	1 lb. (16 oz.)
Hot water	5 qts.
Starch (dry)	6 ozs.
Glycerine	1/3 pt.
Hulled Barley	100 lbs.

The thallium sulphate is dissolved in the five quarts of hot water to which is then added the starch, previously mixed with a little cold water which brings it to the consistency of cream; glycerine is then added. It is important that copper or granite ware vessels be used exclusively in the preparation of these mixtures as there seems to be a chemical reaction with other metals when thallium is in the solution.

Zinc Phosphide Formula No. 1

Whole barley (recleaned)	100 pounds
Lecithin-mineral oil	1 pint
Zinc phosphide (powdered) (Zinc phosphide 90$)	16 ounces

Mix the zinc with lecithin-mineral oil thoroughly; then pour over grain and mix*

Zinc Phosphide Formula No. 2

Oat groats (semi-crushed)	100 pounds
Lecithin-mineral oil (22 ozs. liquid)	2/3 quart
Zinc phosphide (powdered zinc phosphide 90#)	16 ounces

One pound of grain will make 50-60 bait spots.

Anticoagulant Formula

Grain bait	16 pounds
Anticoagulant concentrate (0.5%)	1 pound
Lecithin-mineral oil (warm)	10 to *24* fluid ounces

Thoroughly mix the anticoagulant and the mineral oil; pour over grain and stir thoroughly until all kernels are coated.

In closed mixers the oil may be applied to the bait and mixed until all bait is coated. The powdered material may then be added in dry form. When using the anticoagulant on walnut meats, no oil is needed as the natural oiliness of nut meats will be sufficient.

MIT FORMULAS

For Oregon Ground Squirrel

Strychnine Formula No. 1

Dandelion plants (including roots)	5 gallons
Strychnine (powdered alkaloid)	1 oz
Bicarbonate of soda	1 oz
Saccharin	1/10 oz
Heavy corn sirup	*4* ozs
Thin starch paste	12 ozs
Glycerin	½ oz

Mix thoroughly the powdered strychnine baking soda and saccharin. Crush all lumps of soda. To this add sirup and stir to a smooth, creamy paste. Over this pour thin hot starch paste and stir well* (The starch paste is made by dissolving dry gloss starch in a little cold water which is then added to the boiling water. Boll and stir constantly until a clear thin paste is formed.) Add glycerine and stir thoroughly, making sure that none of the heavy sirup paste sticks to the bottom of the container. Pour this mixture over the bait and mix well so that all bait is coated.

Fresh chicory may be used as a substitute. Green alfalfa leaves are less satisfactory.

Strychnine Formula No. 2

Strychnine coated whole oats for Oregon ground squirrels may be prepared with strychnine formula No. *1}* substitute 25 lbs oats for dandelions. When pouring the mixture over the oats, mix well so that each kernel is evenly coated.

C A U T I O N

All poison containers and all uncleaned utensils used in the preparation of poisons should be kept PIAINLY LABELED and OUT OF REACH of children, irresponsible persons and live stock.

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