

FACTS CONCERNING THE USE OF THALLIUM IN CALIFORNIA
TO POISON RODENTS—ITS DESTRUCTIVENESS TO
GAME BIRDS, SONG BIRDS AND OTHER
VALUABLE WILD LIFE

WITH ONE ILLUSTRATION

By JEAN M. LINSDALE

For the past four years extraordinary efforts have been put forth in California to reduce the number of ground squirrels. Any observant person who spends much time in the portions of the state where these efforts at control have been most active (see fig. 20), cannot fail to learn that squirrel poisoning is one of the most heatedly discussed subjects connected with the out-of-doors. My own interest in this problem was aroused after visits to many of the localities concerned had demonstrated to me that the situation has developed into a really serious one—even more serious than the most partisan protestors have realized.

Much enquiry has convinced me that the present unfortunate conditions have resulted first, from introduction and widespread adoption in this state of thallium as a squirrel poison, and, second, from prosecution of control campaigns with too great vigor. The evidence now available forcibly points to the conclusion that efforts to regulate numbers of ground squirrels can be, and, in some localities, have been, carried to an extreme where the results cause more damage than benefit to the agricultural interests themselves.

Thallium, the metallic element which plays such an important part in the recent revival of interest in squirrel poisoning, was discovered by Crookes in 1861. At about the same time it was isolated and its properties were determined by Lamy. The metal itself is bluish-white and lead-like, and it is insoluble in water. It occurs in pyrites and is found in the flue dust of sulphuric acid works and is prepared by heating thallium iodide with metallic sodium. Although rather widespread in natural occurrence, the whole amount available for use is relatively small.

For the purposes now being considered, thallium salts are used. Of these, thallium acetate has been used for medical purposes and thallium sulphate in rodent poisons. Following its early use, about the end of the last century, to check sweating, its action in causing the loosening and falling out of hair was noted. Most of the information about its poisonous effects in man has been obtained as a result of its use as a hair remover in the treatment of ringworm of the scalp. Hundreds of children have been treated, especially in Mexico and Russia, where this affliction is prevalent. Most, if not all, mammals lose their hair after eating thallium. This is an especially unfortunate feature as regards fur-bearing mammals, which, even if they do not die from eating thallium, are made useless for fur by getting small amounts of it into their systems.

In addition to the knowledge that has accumulated from the therapeutic use of thallium, several workers have made experiments with it upon various laboratory animals. Swain and Bateman concluded, after extensive tests, that thallium deserves to be classed among the most poisonous of the elements and that it progresses in its physiological action with remarkable certainty and definiteness. They demonstrated that it is much more poisonous than lead but ranks close to arsenic, from which, however, it differs in several respects which make it even more dangerous.

The effectiveness of thallium as a rodent poison was tested by Munch (1928). He found that the poisoned baits were consumed with the same eagerness as control

food containing no thallium. The amount of bait offered was one-half to one per cent of the body weight of each animal. In most instances this amount of food was eaten within 15 to 30 minutes after exposure. Twenty-five milligrams of thallium per kilogram of body weight of the rodent was determined as the minimum lethal dose. This amount killed all or nearly all the test animals within five days. One

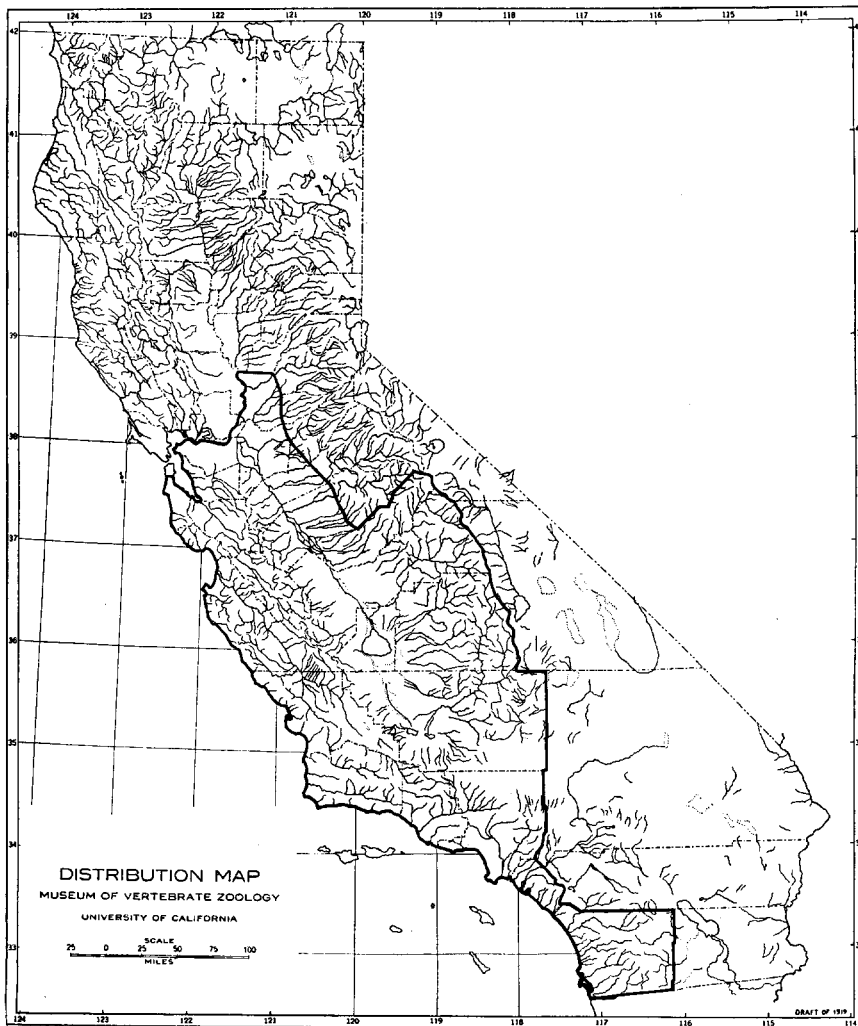


Fig. 20. SHOWING PORTION OF CALIFORNIA AFFECTED BY THALLIUM. THE HEAVY BLACK LINE SURROUNDS THOSE COUNTIES IN WHICH "GROUND SQUIRREL CONTROL" HAS BEEN MOST ACTIVE AND IN WHICH THALLIUM-POISONED GRAIN HAS BEEN SCATTERED.

gram of thallium was contained in each 1.24 grams of the thallium sulphate used. Munch found that death usually occurred on the second or third day after the baits were eaten, unless the quantity of poison eaten was excessive. Ten times the minimum lethal dose killed only one rat of five within one day. Forty times the minimum lethal dose killed only four out of five rats in one day.

Disorders of the nervous system are among the first effects of this poison noticed in animals that have absorbed it. These appear first as a lack of coordination in locomotion and are localized in the hind quarters which gradually become paralyzed. Lynch, Lond and Scovell recently pointed out that it has a definitely selective action on all forms of nervous tissue, and it has been demonstrated that, even in infinitesimal doses, it causes slight degenerative changes in the brain cells of rats. They conclude that it is "most unlikely to leave the human brain entirely unchanged." This last work available (published in December, 1930) shows that "the far-reaching effects of the poison are much greater than is generally supposed."

An instance is cited of a girl who used "on her face a cream for superfluous hairs which contained 2.5 per cent. thallium. Six months later she was still paralyzed and the hair had not regrown. It is probable that sufficient of the cream had been swallowed to produce the symptoms." It has been rather definitely shown that thallium must be absorbed to affect an animal; when applied externally it has no effect. However, there are recent records of workmen, in chemical works where thallium is isolated, getting sufficient amounts of it into their systems to cause serious poisoning.

Animals poisoned with thallium, that have been examined after death, showed the metal to be present in almost every tissue of the body, with less in the skin than any other tissue. This provides a way for certain poisoning of any carnivore which happens to feed upon the carcass of an animal that has died from this poison. Another important aspect of thallium is that it is cumulative in its action. That is, small amounts taken at intervals, unless these intervals are several months apart, will have the same effect as one dose equal to the whole amount taken. In the case of human beings, these small doses are not eliminated for more than ten weeks. According to Devane the poison is gradually excreted by the kidneys, and those organs are especially liable to injury by it.

One experimenter (Ehrhardt, 1927, p. 1374) fed large doses of thallium to a mother rat for four days, when the rat died. The young rats were then transferred to another rat and fed with her milk, but they showed the effects of thallium poisoning.

Unlike many poisons this one appears not to warn, as by a bitter taste, the animal eating it, enough to prevent its getting too much. Its marked slowness in taking effect gives the animals time to get a long distance from where the poison was obtained, thus increasing the danger from secondary poisoning and reducing the chances of finding the bodies of the dead animals.

Still another feature making thallium a certain destroyer is that no satisfactory antidote is known for it. When persons or domestic animals once absorb it, even in small amounts, they are certain to die or to be permanently injured.

As early as 1926, there were reports that plans were being made for the introduction of thallium into California as a squirrel poison. Although it had been used for killing rats in America and especially in Europe, there had been no field applications of it on a large scale in California. The early uses in this state were in field trials, one of them in Santa Clara County.

When this poison was finally given official approval by the agencies in charge of rodent control work, it was adopted quickly in practically every county where squirrels are serious pests. By the close of the 1930 season the counties indicated on the map (fig. 20) had been much more thoroughly worked for squirrel eradication than at any previous time. The aim during each of the preceding four years had been to cover every bit of the cultivated ground and grazing land in those

counties. With the perfection of the organization for scattering the grain, the amount of ground covered was being enlarged each year. This increased amount of activity, resulting in the covering of many millions of acres with poisoned grain, gave a much better opportunity to study the effects of the poisoned grain upon wild life than was afforded on any of the preliminary trials or even during thorough studies on small areas where conditions could not be expected to represent the whole area.

The present analysis is based upon observations of the effects of this poison in every part of the area and covering the whole period of this late campaign. The examples represent nearly every type of ground and of season. Although they do not represent every acre they do include practically every type of situation concerned in squirrel control there. These observations, then, provide a basis which is much more sound than any that has been available previously for the study of this problem. Practically all the persons whose reports have been used live on the ground where the observations were made. They have had, as a rule, a long and intimate acquaintance with the animals concerned and with the other conditions involved, such as climate, native and cultivated vegetation, the local problems of all sorts which affect agriculture, and with all the commonly used methods of rodent control.

Moreover it should be emphasized that these statements do not represent biased statements of personal opinion. Very few of these men have any trace of sentimental prejudice in favor of any kind of wild animal. In fact, many of them hold the opinion that squirrels should be poisoned even if every other wild animal is killed.

Some notion of the extent of the present activity in animal destruction may be gotten from a consideration of the amount of the poison distributed. In fifteen of the counties the amount of thallium-treated grain used in only one year, 1929, averaged 40,641 pounds, and in one county as much as 119,057 pounds was distributed. In addition, each of these counties carried on special activity in squirrel control by other methods such as have been in use for many years.

During 1928, 7,739,070 acres of land in the state were treated for ground squirrels (Ninth Rept. Calif. Dept. Agric., 1929). Out of the total of over 2,000,000 pounds of poisoned grain used, 602,728 pounds were thallium treated.

In the following review of observations, each paragraph represents the important facts learned from one person. In nearly every case, I have been given the evidence orally by the person who made the observation, or I have seen a statement signed by the observer. In addition to the number of animals found killed by squirrel poison and the name of the species, localities and dates are usually given. When the observer knew the kind of poison used it is indicated by a letter (T. for thallium, S. for strychnine). Other significant comments by these persons are added in a few instances. The name and address of the person who furnished any particular item of information can be furnished upon inquiry to the writer.

Alameda County.—About 100 individuals of Lewis woodpecker, California woodpecker, Nuttall woodpecker, red-shafted flicker, California jay, and Brewer black-bird; section northeast of Sunol; spring, 1927 and 1928; poisoned barley and oats. After an earlier campaign for squirrel control between Sunol and Pleasanton, golden eagles went to nearby ranches and made depredations on lambs. Even a dog was carried off by the birds. At one ranch as many as seven eagles were shot in this one season and the species was greatly reduced in that vicinity. Previously, when ground squirrels were available for food as many as four nests of eagles were known near this ranch and no damage to domestic animals was detected.

Many cottontail rabbits; October 1, 1930; near Newark.

Two deer; Mocho Cañon; latter part of September, 1930; (S.) barley. "Find about the same numbers of squirrels in about the same places in the mountains. Have

observed this for years. They do not seem to increase. Believe that coyotes and hawks keep the numbers down."

"After putting out any poison on my place near Mission San Jose, I always keep a close watch for several days to note results. While it takes much more strychnine to kill a bird than it does a squirrel, I find that if a blackbird consumes a good teaspoonful of poisoned grain, it will kill it. I have found a great many blackbirds, meadowlarks, and, when they happen to be present, wild pigeons. I have also found quail, but never where the poison was put out; but they seem always to go to where they roost and die there."

Contra Costa County.—A large number of doves, 4 quail, 15 chickens, 2 geese, 4 turkeys, and 9 cows; in vicinity of Mt. Diablo and Clayton; 1927 to 1930; (T.) hulled barley; squirrels as plentiful as ever in places.

About 48 quail; Mt. Diablo and foothills; 1926; barley.

Three to 5 meadowlarks, 10 to 15 blackbirds; near Pacheco; several years ago; (S.).

Thirty-two pheasants (nearly all in pairs); Bryon Tract; March, 1928; (T.).

Many pheasants, 14 goats, 1 wildcat; Point Orient; 1928; (T.). Fifty-six pheasants were turned loose on this area in 1925. They increased very satisfactorily for the first year or two. Thallium was scattered over the area in 1928 and 1929, resulting in the death of most of the birds. By the end of 1930 only 7 hens and 3 or 4 cocks were left on the Point.

Two valley quail, 5 ground squirrels, 4 Norway rats, 1 jack rabbit, 5 brush rabbits, 3 meadow mice, 4 wood rats, 1 cottontail rabbit; Moraga Valley; 3 hours on September 14, 1927, 4 days after poison had been placed; (T.).

Fresno County.—Poisoned grain is placed in practically all of the foothill districts and the larger portion of the cultivated area.

A number of doves, about 12 quail, several dozen rabbits; in foothills of Fresno Mountains and at Squaw Valley; summer, 1929 and 1930; barley; two chickens killed by thallium in very short time.

Six doves within one-fourth mile on railroad track, blackbirds; nine miles north of Reedley.

About 20 jack rabbits, 6 cottontail rabbits, 1 crow; 60-acre piece on Helm ranch on west side of San Joaquin River; latter part of February, 1929; (T.).

Five cottontail rabbits; near Academy; August 28, 1930; poisoned barley put out by owner.

Three skunks; Squaw Valley; 1927; (S.).

Two doves, 1 skunk, 1 gray fox; Sentinel School district; December, 1925.

Several doves, 5 quail; below Delpiedra on Kings River; August, 1930; (T.). Up to the past year ranchers had poisoned squirrels with strychnine obtained from the county officers. Also the section foreman scatters poison to protect the railway embankment. This year so many dead birds were found that there was much discussion. Next, the ranchers, who had made game refuges out of their places, became alarmed. Meanwhile the birds, which during the dry season had gone to the river for water and had picked up the grain sown from a hand car, had disappeared. Also, all fur-bearers are gone from this locality. One man who kept traps out during nearly the whole 1930-31 season caught only 4 house cats and one opossum on an area where only a few years previously there were many skunks, coons, and coyotes.

Sixty or 70 tame pigeons; near Raisin City; 1930; (T.). All these around one place.

Kern County.—Control is attempted only on the areas most affected.

About 25 doves, many "bean birds", 10 rabbits; near Pattiway; January 1, 1931; (S.); barley and wheat scattered by owner of ranch.

Great many quail, doves, rabbits, and gray foxes; 1 M game refuge along Kern River; within last 5 years.

Two doves, 9 crows, 3 rabbits, 1 dog; Tehachapi Valley, Cummings and Brite valleys, near Tehachapi; August 1, 1930, to September 20, 1930.

Several doves, rabbits and skunks; near Woody; (S.).

Kings County.—Squirrels are considered generally not a serious problem on grazing lands in this county. Control work covers the entire county except a small portion in the southwest part.

Many doves, meadowlarks, blackbirds, turkey vultures, cottontail and jack rabbits; New Home School District west of Gurnsey; May, 1930; (T.).

Los Angeles County.—Work is done in all sections of the County where requested. Improvement on range lands after squirrel control has been estimated at from 20 to 50 per cent.

About 12 doves; near San Dimas; August, 1929. About 100 quail; near Triunfo; July, 1930.

Approximately 15 each of doves, quail, and rabbits; in hills surrounding San Fernando Valley; summer, 1929 and 1930. "Squirrel poisoning is very helpful to farmers. The poisoning of the birds is very unfortunate for sportsmen due to their scarcity already."

Doves, quail, and rabbits; Santa Ana River district; August, September, and October.

One-half dozen quail; 1927 to 1930.

Madera County.—Entire county covered except for high mountain area. Thallium has not been used in the foothill districts.

Many doves; in eastern part of county; summer; poisoned wheat for squirrels. "Do not think doves eat barley as readily as wheat. Badgers have been entirely eradicated by eating dead squirrels. I feel that squirrel poisoning is in a large measure responsible for the terrific lessening in the number of doves. Poison should be placed in winter when doves are not present."

As many as ten in one small field of doves, quail, meadowlarks, and gray foxes; at own place near Raymond; August and September, 1929 and 1930; poisoned wheat.

Ten or more of quail, jays, and squirrels; on own ranch; in summer; barley, "The average person putting this poison out clears his fields of stock, then broadcasts the grain at random over the land in different places and kills the squirrels—yes, and quail and other birds also. Where coveys of from 50 to 100 quail used to be seen here, there are now a few coveys of eight or ten birds."

Quail, coons, opossums, and dogs; on Chowchilla River.

Doves; Raymond.

Four badgers; August; poisoned by eating squirrels killed with wheat.

Many doves, gray squirrels, cottontail and brush rabbits; North Fork and Coarse Gold; June 15, 1929; May 20, 1930; July 30, 1930.

Lots of doves; in foothill country; late spring and early summer; hulled barley.

"Birds and rabbits have been found dead every year after poisoned barley was used on ranch near Mist. Have complied with poisoning request for the past ten years and each year have noticed, and others have also, that many kinds of birds, rabbits and skunks are found dead. A quail is not easily found because when it becomes sick it will hide and die. Birds that live in trees are most generally found because they drop on the ground. Quail have been protected on this ranch of 800 acres for the past ten years, but they are decreasing very rapidly. It must be the poisoned grain and not hunters in this case."

Particular flocks of quail disappeared or were greatly reduced after thallium was placed out, but, in these instances, no dead birds could be found. Thought that animals crawled into brush to die. The hunters in this district have been unable to find quail this year (1930).

Merced County.—Thallium has been used almost entirely in this county within recent years. In 1930 special efforts were made to cover the whole county consisting of about one and one-quarter million acres. Officials think that coyotes are being reduced in number to an easily appreciable degree due to squirrel poisoning operations.

Eighty dead geese of five kinds: Cackling, Hutchins, Canada, White-fronted, and Snow; around Lake Yosemite; December 1, 1930, to February 1, 1931. "Grain was found in the gullets of several of these birds. Yosemite Lake is resorted to as a loafing ground for geese that feed all over the general territory."

Sixty dead and dying geese along one mile of shore line at Lake Yosemite; December 10, 1930. This instance reported by P. A. Shaw in *Outdoor Life* (67, 1931, p. 42) who continued, "I have since been informed that ten to thirty additional geese died each day up to December 20, one report stating that sixty-five were counted on December 20. I believe that 250 to 300 would be a conservative

estimate of the total fatality. Qualitative tests for thallium by means of the spectro-scope were positive on thirty-two of the geese collected, and the diagnosis of thallium poisoning has now been fully verified by quantitative determination of thallium deposited in the edible tissues. Geese collected on December 18, and examined by another laboratory, indicate that phosphorus was responsible for many of the deaths. It is reported that phosphorus grain was distributed over a large acreage for the ten days preceding December 19. Since two poisons have contributed to the death of geese in the Merced area it is impossible to state which has caused the major damage. However, in so far as this laboratory has investigated, all deaths have been due to thallium."

Forty-six sheep; near El Nido; 1928 (T.). From an item in *Outdoor Life* (67, 1931, p. 42), which also states that "Wolfsen further claimed the land was unfit for pasture for six months until rains had washed the poison away. He asked \$1,190 damages for the death of the sheep and subsequent unfitness of the land."

Six quail; foothills, eastern side of valley; (T.); hulled barley.

A great number of doves, quail, and skunks; near San Joaquin River and Panoche Plains; November and December, 1929.

Quail; near Delhi; (T.).

A few coyotes from eating poisoned squirrels; near Planada.

Meadowlarks, blackbirds, cottontail rabbits, brush rabbits, jack rabbits, skunks, and one coon; near Snelling.

Quite a few quail, doves, and meadowlarks; around Merced River country; in spring.

Monterey County.—Only parts of the county are covered each year. Six to ten men are kept in the field. Persons in charge of pest control here realize that "there never has been an animal pest, so numerous as squirrels, eradicated."

Forty quail on Zacher's Ranch, 6 quail and 8 doves on ranch back of King City; September, 1929; (T.).

Four quail, numerous sparrows, blackbirds and larks; foothills of Gabilan range east of Salinas; last two weeks of May, 1930; (T.). "I personally watched the poison being put out and it was not put in the runs or burrows but was scattered everywhere. We have used strychnine poison for years on our range lands for squirrels and have not found any dead birds of any description that we could trace back to the poison, but at the time the squirrel drive was on, dead birds of all description were easily found anywhere within two miles of the outside of the thallium poisoned area."

Three or 4 doves, 5 or 6 woodpeckers and linnets; Angell Ranch near Pleyto; April, 1930; (T. and S.). "To thoroughly poison the squirrels it would be extremely difficult and expensive to keep from killing a few birds and rabbits."

Two crows and 4 or 5 blackbirds; Doud Ranch near King City; between April 1 and 30, 1930; (T.). "My ranch has a little over 2000 acres and I used 1800 pounds of poisoned barley [T.] with good success. I did not see any dead animal with the exception of one dead rabbit. It looks to me as if the squirrels died inside their holes for I did not see a single dead squirrel on top of the ground."

One deer, a yearling doe (my friends have picked up dead quail); David Jack's property; 1929; (T.). "Reports have come to me from different land-lords that their ranches have been almost completely cleaned up as far as quail, doves, and rabbits go and there is no doubt that the scarcity of quail in Monterey County during the last few years has been caused by the use of thallium in the squirrel poisoning campaign. I have had good success in poisoning squirrels by the use of strychnine and barley and do not recall ever poisoning any quail, doves and rabbits. The use of wheat in any event is very bad."

Eight quail; Gabilan; March, 1930; (T.).

Orange County.—Thirty men working for about sixty days attempt to cover all the infested territory in this county.

Twenty to 30 doves, 12 quail, crows, 25 chickens, 15 or 20 rabbits; Telegraph Cañon; April, 1930; (T.). "Even sheep were killed, but county made good in this case."

About 25 doves; Orangethorp and Cypress Road; first part of July, 1930.

Eight quail, 2 sheep; Santa Ana Cañon; last of March and first of April. "Have had reports where almost whole bands of quail disappeared but saw no dead quail."

Several quail, doves, and rabbits; Olinda and Yerba Linda hills. "There are no quail in this locality and not a rabbit to be seen. They have all been killed off by the county putting out some kind of squirrel poison. I know of one man that lost 20 chickens from the grain."

Many doves and rabbits and a few quail; entire foothill section; 1928 and 1929; (T.). "Too much carelessness in placing poison in large amounts outside of squirrel holes, often dumped in shrubbery and cactus where no holes at all."

A news item sent out by the United Press from Anaheim, March 5, 1931, states that "one child was dead and four other persons suffered from paralysis after eating mush prepared from poisoned grain." According to this clipping, one of the victims "found a bag of wheat in a ranch house and took a quantity home to prepare a meal. Thallium, used as a squirrel poison, had been added to the wheat."

San Benito County.—Quite a number of quail and rabbits; near Pacheco Pass; past two years; (T.).

Doves and jackrabbits (not counted); (T. and S.). "There were some deer poisoned this year for the first time. They ate the thallium grain."

Rabbits, doves, larks, magpies and jays; on own ranch near Paicines; (S.).

San Diego County.—Entire county except mountains and waste land, covered each year.

Few cottontail rabbits. Estimated 50 doves; Coogan Ranch; June 17, 1927. Estimated 500 doves; Jamul Ranch; April 13, 1928. Estimated 2000 doves; Guejito Ranch; June 21, 1928. (S.). "These birds badly decomposed. No quail found although quail inhabit these same localities. At time these birds were poisoned, poison barley was broadcasted. Squirrel control campaigns should be either stopped or continued on a larger scale by poisoning cats, skunks, foxes, etc. As their natural food is taken away, it forces these animals to take game birds and animals beyond question."

Two hundred doves (estimated 500 killed); Jamul Ranch; April, 1928.

Four hundred doves; Jamul Ranch; 1928.

Comparatively few doves, linnets, rabbits, white-footed mice, and kangaroo rats; over most of county; 1929 and 1930; (T. and S.).

A large number of doves; two or three years ago.

Two valley quail, 1 Anthony towhee, 3 cottontails, and 1 brush rabbit; Lake Wohlford; May, 1930; (T.). "I did not see any poison except in holes or protected places."

Seventeen jays, 1 tree squirrel; Laguna Mountains; September and October, 1929; (S.). "They were around a camp ground which was badly infested with ground squirrels."

Several doves, 1 coyote; own ranch at Mesa Grande; 1929. "Doves up to normal now. Owing to heavy, late snow and rains very few young quail this year."

No estimate (not a large number) mice, kangaroo rats, rabbits, sparrows and linnets; during spring of 1929 and 1930; (T. and S.). "Proper care was used."

Quite a number of valley quail; Otay Mesa and near La Mesa; summer of 1929. "One of the two farmers talked to thought the campaigns valuable. The other was quite indignant over the killing of the birds."

Several dozen doves, rabbits, and gray squirrels; Wynota Valley; August, 1930; (S.).

San Joaquin County.—Forty-five quail, several skunks, hundreds of cottontails; Stewart Tract about 15 miles WSW. Stockton; March 6 and 12, 1928; (T.) hulled barley. "In the above case the poisoned grain was thrown all over the field, starting at one levee and continuing across the field to the other levee. A noted decrease in skunks caused by their eating other poisoned animals and birds. I have also found several other species of birds that were poisoned but was unable to ascertain just what poison was used."

Twenty-eight quail, 9 cottontails; Salmon Slough, Old River, and Stewart Tract; February or March, 1928; (T.). "On all the low land the ground is wet enough so it can be cleaned of squirrels with carbon bisulphide. Poison kills pheasants, quail and cottontail. I am not in favor of poisoning along levees."

Seventy-five valley quail, 60 meadowlarks, 40 doves, and 300 cottontail rabbits; Tracy; March 6 and 12, 1928; (T.).

Nine quail, 27 rabbits; lower division Roberts Island; November, 1928 and 1929.

An observer, on April 27, 1928, along 11 miles of a highway, beginning four

miles west of Stockton and thence west, saw approximately 14 live weasels cross the road ahead of his car and noted about as many dead ones on the highway in the same stretch of 11 miles. The live ones were seen singly (not in a bunch) and each weasel, with one exception, was going north. None was seen going south. The exception was one eating on a gopher snake that lay on the highway. On April 28, only the remains of one dead weasel could be found on the same stretch of road. Inquiry of four local residents in the neighborhood elicited the reply that each, in a recent trip over this road, had seen weasels crossing the road. These were the first individuals seen by any of these people for some time. A possible cause for this unusual movement of the weasels was suggested when it was learned that within one or two months previously, several thousand acres, beginning two miles south of this highway, had been covered with thallium-treated grain. One investigator learned that more than 500 valley quail, about 200 cottontail rabbits, more than 400 jackrabbits, many small passerine birds, numerous skunks as well as squirrels and other small animals had been killed. Evidently, as a result of the depleted food supply, the weasels left the area and traveled northward. Water surrounded the area on the west, east and south.

San Luis Obispo County.—Concerted campaign with thallium begun in 1928. One-half of county covered in 1929, three-fourths covered in 1930. As many as fifty crew foremen used at one time. Greater amount of thallium used than in any other county.

Several dozen doves and quail; Palo Prieto Ranch; 1928, 1929 and 1930; (T.) barley. "The poisoned grain was scattered broadcast over the ground. They kill about as many doves and quail as they do squirrels."

Few doves, linnets, ground birds, jays, and jack rabbits; past two years; (T.). "During that time, I have found several coyote carcasses undoubtedly killed by eating poisoned squirrels. In this locality coyotes were formerly very numerous. During the last eight months, I have not seen a live coyote and I am out on the range almost every day. Quail, formerly quite numerous, are becoming quite scarce, but I do not think many of them get poisoned."

Four golden eagles, 4 red-tailed hawks, 20 yellow-billed magpies; Paso Robles and Shandon; March 1 to 25, 1928; phosphorus. "I have seen a coyote last three days before it died."

"The poisoning of squirrels with thallium has killed off the coyotes, and I notice while riding the range that most every doe has two fawns this season which is very unusual."

Many rats, very few rabbits and doves; east of San Miguel; three years ago; (T.). "Many quail on my ranch and I have never found any signs of them having been killed."

Very few rabbits, crows, magpies and jays; northern part of county; 1928, 1929, 1930.

Hundreds of birds, rabbits, dogs, skunks, cats; around Shandon; spring, 1929.

Two quail, 3 doves; 1928; (T.).

Santa Barbara County.—Entire county covered by intensive work for three years. As many as twenty-five men employed at one time in placing grain.

Six quail, 11 doves; Buellton; December, 1929.

Coyotes and wildcats; Santa Barbara Forest; May, June, September and October; (T.) oats and (S.) barley. "Several tons of poison were put out on and adjacent to the forest during the current year, and only a few coyotes and wildcats were found killed.

Several tree squirrels; Santa Ynez Valley and Montecito; 1929; (T.). "Having charge of several properties in Santa Barbara County, one of which consists of a six thousand acre ranch, I am convinced that the present method of broadcasting squirrel poison causes a reduction in the number of birds and other wild life where such methods are used."

Five wildcats; near Los Alamos; in past two years; (T.). "On 15,000 acres of land formerly one of worst squirrel-infested in the county, I have watched very closely all of these campaigns, and I have as yet to see any birds that have been killed, but I have seen coyotes and wildcats that I am sure were killed by eating squirrels that had been poisoned."

Santa Clara County.—Entire county covered during last four years. Greater dependence placed on strychnine than upon thallium.

Fifteen chickens; near Los Gatos, Shannon road; fall of 1927; (T.).

Jays, blackbirds, coons, skunks, rabbits; southeastern part of county; over period of four years; (T. and S.).

About 15 or 20 quail in one place; 1925.

Three coons, 5 skunks; east of Gilroy; winter of 1929.

Three or 4 rabbits; Pacheco Pass; August, 1928; (T.). "In orchard. Rabbits and squirrels lived together and were considered equal pests."

Raccoons, skunks, opossums. "They have done their work as far as squirrels are concerned, also killing all the rabbits and many varieties of birds. The quail have about all disappeared from their haunts."

"One man put out 50 pounds of poisoned grain. I was there about two weeks later and counted 27 dead rabbits and 7 quail and found the squirrels still in good health. This year the man who does the squirrel poisoning in this section came on my mother's ranch in the dove nesting season. In going through an oak grove, just on the low limbs I could see from the ground in a three-hour search, I found 29 dove nests with either dead young or rotten eggs. Also three pheasants, one badly mangled, but two stiff with no wounds on them. Two years ago on the same ranch some poison was put out about 200 yards from the house with no squirrels within a quarter of a mile, and it got 18 chickens."

The following report is from a man in Morgan Hill: "Enclosed golden-crowned sparrow is one of three found dead near my house here yesterday and today. I do not recall finding a single one heretofore, that is, dead, in fourteen years. Two of these I found myself this morning right under a heavy vine where they are in the habit of roosting. The squirrel man from the Department of Horticulture was here two or three days ago and put out hulled barley treated with thallium. He assured me that birds would not take this barley, though he admitted my suggestion that doves might be an exception." A little hulled barley was found in the stomach of the bird saved. October 18, 1926. The same man wrote on November 26, 1926, as follows: "Have found several other dead birds, a couple right with the poison, including quail—and a screech owl near the remains of the quail—white-crowned sparrows, juncos, towhees."

Santa Cruz County.—Entire county covered. Special attention to this work for four years.

One hundred and fifty quail (reported to one man); summer of 1929; (T.).

Stanislaus County.—Intense campaign with thallium began in 1930. Aim is to cover entire county. Nearly fifty men employed to spread thallium-treated grain during first season of its use.

Eight quail; along south shore of Don Pedro Lake; August, 1930.

Tulare County.—Cover all cultivated and grazing lands comprising about one million acres. Fifteen men employed.

Four doves; hill country east of Lindsay; August, 1930; (T. and S.).

Sixty doves, 15 quail; September 1 to 23, 1930. "In one place there was a man driving the truck and the other on the back of the truck throwing the grain out along the road as they drove along."

Five hundred to 750 doves, 50 quail, 4 coons, 40 to 50 skunks; vicinity of Lemon Cove and Three Rivers; 1924 to present.

Five doves, 4 civet cats; about November 20, 1930.

Three doves, 5 wild pigeons, 1 brush rabbit; Cottonwood School District; July, 1930; barley.

Four quail (with barley in stomachs), jays and wild pigeons; near Springville; July and August, 1930. "The poisoned squirrels have been a death blow to the coyotes in a little valley in the edge of the foothills north of Porterville. I have seen some dead ones off from the road in that section."

Several quail and doves; foothills; November 15 to 30, 1929. "No quail now, where plentiful before."

Several each of quail, doves, wild pigeons, gray squirrels; lower Kaweah River watershed; one afternoon in November, 1925. "Poisoning squirrels robs the fur bearer of easiest meat supply causing him to kill poultry and livestock."

Many pigeons, quail, doves, skunks, opossums, and coon; along lower portion

of Kaweah River. This family, and "all the people around like to eat the squirrels, even in preference to other kinds of game. They do not take away matter from the soil, as is the case when land is grazed and the meat sold, or when a crop is harvested. Either they furnish natural food for carnivores or themselves die and help to build soil. When they are removed, then the predators must go without food or go to the ranches where they become pests."

Three quail, 2 doves, 5 rabbits; Woodlake; September 15 to 25, 1930; (T.).

Ventura County.—One or two doves, pigeons; Cuyama Valley; barley.

Two doves, 4 quail; 1928; (T.).

Eight doves, 3 gray squirrels; Santa Susana; (T. and S.).

"A house cat got a squirrel and took three weeks to die. A mule was turned out in the pasture Saturday morning where a lot of the poison had been put out a week or two before and it died Sunday. We believe it saw the oats (he would not have seen them if there had not been a little pile) and ate them. Casitas Pass, in July. Two or three years ago on our ranch, before any poison had been put out, there were lots of foxes and bob cats, but today there are no bob cats and few foxes."

Few brown birds, 2 doves; Santa Paula Cañon and out on Foothill Road; summer, 1929; (T.).

One-half dozen or more towhees and white-crowned sparrows, 12 or more cottontail rabbits and kangaroo rats; Santa Susana; March, 1929.

Records not assigned to counties.—More than 60 valley quail, 9 mourning doves, 4 crows, 3 Nuttall sparrows, 9 red-winged blackbirds, 4 meadowlarks, 8 spurred towhees, 3 lark sparrows, 4 ravens, 9 Brewer blackbirds, 4 striped skunks, 2 weasels, 1 coon, more than 60 cottontail rabbits; San Joaquin, Kern, Contra Costa, San Mateo, and San Benito counties; 1928, 1929, and 1930; (T., S., and Phosphorus). These animals were found by one person who had special opportunities to observe squirrel control operations.

A summary of the relatively meager observations recorded in this report shows that the lowest possible number of kinds of animals killed by squirrel poison, other than squirrels is sixty. A list of these follows with the total number of individuals actually found and reported for each. (When inclusive estimates were given, the lowest figure was taken.)

Mourning dove.....	3314	Woodrat	4
Valley quail.....	713	Nuttall sparrow.....	3
Cottontail rabbit.....	490	Lark sparrow.....	3
Tame chickens.....	95	Meadow mouse.....	3
Pheasants	82	Deer	3
Wild geese (5 species).....	80	Golden-crowned sparrow.....	3
Meadowlark	67	Gray squirrel.....	3
Tame pigeon.....	60	Weasel	2
Striped skunk.....	53	Tame geese.....	2
Sheep	48	Dog	1
Brewer blackbird.....	23	House cat.....	1
Jack-rabbit	21	Gray fox.....	1
Yellow-billed magpie.....	20	Coyote	1
Crow	16	Anthony towhee.....	1
Goat	14	Screech owl.....	1
Cows	9	Mule	1
Red-winged blackbird.....	9	Lewis woodpecker.....	
Coon	8	California woodpecker.....	
Spurred towhee.....	8	Nuttall woodpecker.....	
Brush rabbit.....	7	Red-shafted flicker.....	
Wild cat.....	6	California jay.....	
Turkey	4	Wild pigeon.....	
Civet cat.....	4	Turkey vulture.....	
Badger	4	Opossum	
Red-tailed hawk.....	4	Linnet	
Golden eagle.....	4	White-footed mouse.....	
Raven	4	Kangaroo rat.....	
Norway rat.....	4	Junco	

The long series of facts just presented indicate the great variety of animals which lose their lives directly or indirectly from the use of thallium in California. However, they are wholly insufficient for judging the total number of individuals which die in this manner. Although these counts reach into thousands, even for single species, they represent observations on only a small fraction of the whole area treated with poison. The whole number of animals killed must be many times greater than is indicated by the figures given here.

Some additional factors which must be considered in a final solution of the problem of squirrel control are suggested in the following paragraphs.

Among the birds most frequently poisoned, mourning doves take the grain readily, with certain death following. There is loss not only of the adult birds but often also of broods of young or sets of partly incubated eggs. If the poison is scattered in early summer it takes all the birds that have successfully passed many dangers, the breeding stock, and hence it results in a greater loss to the species than if an equal number of birds were poisoned at some other season. If the poison is scattered at a season when these birds are gone, it is likely to result in a lesser squirrel reduction. There is small possibility of exterminating the mourning dove from the United States, but squirrel control continued as in the past four years is almost sure to lead to removal of this bird as a common summer resident in the area marked on the map (p. 93). Further, it seems probable that any process of restocking of doves from outside areas would be a slow one.

Pheasants appear to suffer greater losses than any other kind of bird on the poisoned areas. Chances for survival of these introduced birds are meager at best, but when thallium-treated grain is scattered on their feeding ground there is no chance for them to survive. Persons interested in the propagation of this bird should select, for stocking, some area outside the range covered with thallium.

Valley quail are affected by thallium poisoning campaigns, but as yet it is impossible to foresee whether this factor will be sufficient actually to cause the disappearance of the species from the area. It has been definitely established that quail will eat thallium-treated barley, and that they are killed by it. Also, the facts that whole coveys have disappeared from poisoned ground and that the species became so reduced in whole counties as to be not worth hunting have been observed. However, it is certain that during the past two seasons quail have suffered severe losses from other causes, such as cold fogs and rains during the nesting seasons and the long drouths which have reduced the normal amount of food. Another factor which must be considered is that in those places where rodents have been poisoned and flesh-eating animals have not been killed off by eating poisoned carcasses the carnivores constitute an additional hindrance to the maintenance of quail numbers.

Squirrel control with thallium has an important influence upon fur-bearing animals, of the kinds which provide nearly all the income to trappers in California. Those animals most affected are skunk, wild cat, coyote, gray fox, coon, and opossum. All of these will eat the bodies of dead animals that have been killed with thallium. The facts reported above show that where ground has been poisoned almost every animal upon which this group depends for food is killed. If these secondary feeders are not quickly killed, their pelts are almost certain to be ruined for fur because, as has been pointed out, the loss of hair is one of the known effects of thallium upon animals.

Another possibility of which there are examples is that when the food for carnivores (both birds and mammals) is quickly removed these latter animals leave the usual feeding ground in search of sustenance. On such occasions the only places

where food can be obtained are the farmyards. The hungry animals, the ones which do not starve, congregate there and thus make necessary another pest control campaign.

All representatives of this group of flesh eaters are slow breeders when compared with the grain feeders which are poisoned first. It is to be expected, then, that once they are removed from the large area which has been affected in California, a long period of years will be necessary to restore them to desirable numbers,—that is, provided the intensive poisoning is not continued. In the latter case there can be no return of carnivores. During this slow period of recuperation, hunting and trapping for fur cannot be profitable in these districts and demands for extra activity in pest control are to be expected, for rodents and vegetable feeders can repopulate an area at a faster rate than can carnivores; besides, the rodents would not be hindered in their increase by carnivores.

Still another point in this connection is that, with continued special activity in this type of pest control, progressively fewer examples may be available to demonstrate the effects of the poison on other animals than the pests. It may be that only the pests will be able to persist.

As to the effects of extensive poison campaigns upon the California digger ground squirrels, it is now recognized by practically all workers that they cannot hope ever to remove this animal from California or to prevent its reinvading small areas whence it has been removed. It has been learned (Jacobsen, 1923, p. 58) that in the case of this ground squirrel (*Citellus beecheyi beecheyi*) on an area where there had been consistent control for two years or longer "the litters were uniformly larger than on areas where the work had either just been started this year or had been in force for eight or nine months". If this discovery holds in the case of other rodents, there is a possibility that some one or more of these species, which hitherto have been present in numbers that were kept down by the effects of normal factors in their environment, might develop into serious pests.

It has been demonstrated many times in the past four years, in California, that the use of thallium poisoned grain, along with and in addition to the other methods of squirrel killing, will kill great numbers of squirrels. The immediate effect of this poison on the squirrel pest is of the same sort as upon other kinds of animals. However, it has not been proved that this great reduction of squirrels temporarily has justified the high cost of the poison and of the labor required in placing it. Much of the protestation against its use has come from farmers in the foothill sections where squirrels provide only one of the serious problems confronting them.

Workers on areas where poisoned grain has been scattered often remark that they have never seen any dead animals. This does not mean necessarily that no animals were killed, for in the case of a slow-acting poison there is a strong probability that most of the poisoned animals will reach hiding places before they die. Also it is not to be expected that these workers will be sufficiently careful observers to discover carcasses other than the most exposed ones.

During the early years of the use of thallium in California, the United States Bureau of Biological Survey attempted to exercise the closest possible control on the introduction and use of this poison. A letter written by the Chief of the Bureau on December 9, 1926, states that "it has been directly through our persistent efforts that the general use of thallium has been prevented and we shall continue to exercise the same efforts to have this done in the future".

However, in an article on rodent control investigations in California, a representative of the Biological Survey in 1928 published directions for the use of thallium,

along with a warning as to the possible dangers in its use. That this federal agency still approves the use of thallium is shown by the latest recommendations, available in February, 1931. These mimeographed instructions contain no hint of any important change in recommended method of procedure from the one that has been followed during the whole period of use of thallium. In other words, there is every indication that the sort of practices reviewed in this report will continue in California, unless checked through public protest. My studies indicate that throughout the period of the intensive use of thallium the county authorities have made a determined effort to follow explicitly the instructions supplied them. There is a remarkable uniformity in the methods employed in the counties where there was greatest activity.

After a careful study of the material mentioned in this discussion, and a consideration of the natural history of each animal concerned and of other related phases of agriculture in California, it is possible to offer some comments as to future ground squirrel control. Possibilities for the future may be thought of as leading in one of three general directions.

1. The attempt to control squirrels might be stopped altogether. This course has been advocated by some people, but it really does not merit serious consideration.

2. Authorities may develop more and more extensive and more thorough campaigns for artificial "control" of wild life. This leads rather directly to a constant war on all animals except the domesticated ones, and necessitates a certain allowance for loss to these and even to man. Trends in agricultural administration in late years seem to indicate that a large proportion of the leaders in that industry advocate such drastic action as this, but that they have given little thought to the ultimate outcome of such practices.

3. A policy for squirrel reduction may be developed on a different basis of attack from any so far used. The aim, instead of being for as much killing as possible would be for as little as possible. That is, an attempt would be made to reduce the losses to crops rather than solely to kill squirrels. Such a policy would take advantage of as many natural checks upon squirrels as possible, but also, especially on cultivated lands, it would take greater precautions in artificial reduction in order to save as many animals as possible.

Some of the difficulties involved in such a program would be avoided if the squirrel control supervisors and field foremen were required to pass a test in basic knowledge of natural history. In most cases the experience of these men in the field gives all the knowledge of squirrels which they need. What is lacking is an appreciation of the kinds of interrelations which exist between the organisms in the areas concerned. These are not necessarily the same in detail in all localities.

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