An Aerial Method of Dispensing Ground Squirrel Bait

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Highlight

A need for improving and updating rodent-control methodology prompted this study of the use of aircraft for baiting destructive populations of ground squirrels. Both spot and strip baiting by air were effective when applied in narrow swaths at a rate of 6 lb/swath acre. The aerial technique of dispersing bait gave good control when the ground squirrel population was foraging extensively for seed. The bait need be applied to only a fraction of the ground surface of squirrel-infested rangeland.

Metodo Aereo de Dispersar Cebo Envenenado para Ardillas (*Citellus beecheyi*)

Resumen[2]

El uso de aeroplanos para diseminar cebos de granos envenenados para controlar las ardillas (*Citellus beecheyi*), una de las plagas mayores de los pastizales en varios estados del Oeste de Estados Unidos, ha probado ser efectivo en California.

Los cebos aéreos toman ventaja de la habilidad forrajera de las ardillas para localizar y consumir una cantidad fatal de cebos ampliamente dispersados al voleo. Semillas de avena tratadas con 0.070 a 0.113% de fluoracetato de sodio (1080) a 6 lb por una franja de un acre dio buen control de ardillas si se aplica al tiempo cuando las ardillas estuvieran alimentándose con semillas y no estuvieran invernando. El cebo necesita ser aplicado a únicamente una fracción de la superficie del suelo si se hace al tiempo del año cuando toda la población de ardillas está activa en la superficie alimentándose extensivamente con semillas; entonces ambos cebos en franjas y manchones al voleo por avión dan resultados satisfactorios, usando las franjas mas estrechas conseguidas por el avión.

Otras especies de roedores son afectados por el tratamiento en grados variables, pero no hubo evidencia de pérdidas de aves de caza. Los invertebrados y el clima son factores importantes que contribuyen a la degradación del cebo. La técnica no es un remedio universal para el control de las ardillas, mas bien es un método avanzado que será útil en muchas situaciones. Si es usado con discreción la distribución de cebos por avión es una herramienta segura y de valor para el control de ardillas en los potreros del Oeste.

This study was made principally to determine the effectiveness of aerial baiting for controlling ground squirrels (*Citellus* spp.), a major pest of rangeland in California and other western states (Fitch, 1948). Traditionally, control is conducted by hand-baiting methods that involves placing or scattering a spoonful of grain bait near each burrow opening, moving from burrow to burrow on horseback or on foot. Aerial broadcasting, in contrast, relies on the squirrel's natural ability to forage

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widely in the vicinity of their colony. Aerial broadcasting of squirrel bait has already been explored on a limited basis (Howard et al., 1956), without determining precise rates and application procedures.

First, it was necessary to establish the amount of bait and concentration of rodenticide needed to ensure that each squirrel would be able to locate and consume a lethal quantity before any unpleasant symptoms occurred. If the toxic level of the bait is too high, acceptance may decrease, and broadcasting too much bait contaminates the environment unnecessarily. Conversely, if bait density or concentration of toxicant is too low, ingestion of sublethal amounts may cause bait shyness (Howard, 1959), giving poor control. Also studied were the effects of aerial baiting on nontarget species, and the fate of bait not taken by squirrels.

Study Areas and Procedures

In developing the technique and evaluating the effectiveness of aerial baiting of ground squirrels, treatment was applied to more than 207,000 acres in California, mostly rangeland and mostly in San Luis Obispo County. Two subspecies of ground squirrels were involved: the Fisher ground squirrel (*C. beecheyi fisheri*), on the Fickert property (Kern County), Newhall property (Merced County), and Boswell property (Tulare County); and Beechey ground squirrel (*C. b. beecheyi*), on the Ketchum property and the Carriso, Santa Margarita, and Lewis ranches in San Luis Obispo County. Since both subspecies range from oak woodland to grassland habitat and responded similarly to control efforts, they are evaluated together.

To evaluate the acceptance of grain baits by squirrels prior to each aerial application, bait containing all of the ingredients except the toxicant was broadcast with a small cyclone seeder at 6 lb/acre in the vicinity of "sample" colonies.

The experiments made use of four different makes of fixed-wing aircraft and one helicopter. The standard seed-sowing gates of most aircraft need some minor modifications before they can deliver bait at rates that are low enough. The desired narrow swaths (less than 45 ft wide) were achieved by removing or altering the spreading devices (vanes or airfoil-like equipment) used on aircraft to increase seeding swath widths (Marsh, 1967).

Two approaches to aerial baiting were explored: 1) applying the bait in parallel swaths (stripping) across squirrel-infested rangeland; and 2) spot broadcasting, in which the pilot applies a short swath on or within the foraging distance of each colony. Both approaches were sometimes used on different portions of the same property, depending on squirrel density. Parallel swaths were spaced up to 260 ft apart. Two flagmen were used in open flat terrain to establish the desired interval between swaths.

Regardless of which type of aerial application was used, each pilot was first oriented to the ranch boundaries by means of aerial photographs and topographic or other maps. Squirrel-infested areas were outlined, and special instructions were given the pilot on areas not to be treated, e.g., around farm buildings, public roads, streams, water troughs, property lines, and the like. Ground-to-air radio communication was used on some ranches to keep the pilot oriented. Baits were generally applied during the early morning hours, from heights of about 50 ft and at air speeds of about 90 mph. Grain baits are sufficiently heavy that drift presents no problem in calm air, but winds exceeding 15 mph hamper accurate bait placement by spot broadcasting.

Used in all tests were crimped oat groats (hulled oats that have been lightly steam-rolled) treated with sodium fluoroacetate (1080). The poison concentrations evaluated were 0.056, 0.070, 0.084, and 0.113%, respectively equivalent to 1.0, 1.25, 1.5, and 2.0 oz of compound 1080 formulated on 100 lb of grain. Bright-yellow dye was added to the bait to repel seed-eating birds (Kalmbach, 1943) and to distinguish treated bait from clean grain. Bait was applied on different parcels of land at rates per swath-acre of 4 lb (1.6 kernels/ft^2) to 14 lb (5.7 kernels/ft^2).

The degree of squirrel control was evaluated on 46,610 acres, on 7 selected ranges, on the basis of repeated pre- and post-treatment squirrel counts made from selected observation points. On some ranches, road counts provided the most useful census, for larger areas could then be censused. Counts were repeated several days in succession, at a time in the morning or afternoon when squirrel activity was highest. This method of evaluating results is, of course, subject to errors, but it was felt to be adequate from a practical view. The numbers of squirrels counted pretreatment per day provided an adequate sample size because they were always in excess of 50 animals. Visual censusing of squirrels provided more useful information for evaluating the degree of control achieved over large acreages than did either of the much more restrictive censusing methods of live trapping, marking, and releasing, or of counting the number of artificially plugged squirrel burrows that were opened by the surviving squirrels. The validity of these measurements of control received support from the number of dead squirrels observed and the fact that all observers had had much previous experience in squirrel control.

The influence of aerial broadcast baits on other animal life of the biotic community was monitored. Censuses were taken of small rodent populations by setting out lines of snap traps (a total of 4,400 trap-nights) before and after treatment on several ranches. Members of the California Fish and Game Department made frequent wildlife counts to monitor effects on game birds and other nonrodent species. Populations of game animals were surveyed on selected properties, and visual counts were made pre- and post-treatment. Since searching parties were generally limited to about 6 men, it was impossible to cover entire ranches; monitored areas represented only portions of individual ranches. Monitoring included rather extensive searches within habitats that, prior to treatment, had been determined as being the most suitable areas for game species. These areas were selected with bias toward determining the maximum effects that the treatment might have on nontarget species.

To measure consumption of bait by invertebrates, sample plots were established. Each consisted of 20 kernels placed on the ground and covered with a 0.25-inch hardware-cloth-mesh cage (17 × 17 × 4 inches) to exclude all vertebrates and the larger invertebrates. The degree of consumption of bait by invertebrates was recorded by the rate of disappearance of kernels from beneath these small cages.

Table 1. Percent control (to the nearest whole number) of ground squirrels resulting from two types of aerial application of different rates of 0.113% 1080-treated crimped oat groats.

Property	Date of application	Acres treated (gross)	Rate/swath-acre (lb)	Kernels of bait/ ft²	Type of application	Squirrel control (%)	Reasons attributed to reduced control[1]
Fickert	10/64	2,000	14	5.7	Stripping	86	2
Carriso	6/64	21,000	12	4.9	Spot broadcast	98	—
Santa Margarita	9/64	1,100	9	3.7	Spot broadcast	73	2
Lewis	6/65	7,300	6	2.4	Stripping & spot broadcast	91	—
Camatta	5/66	11,000	6	2.4	Spot broadcast	96	—
Newhall	7/65	640	5	2.0	Stripping	74	1, 2
Newhall	6/66	640	4	1.6	Stripping	70	1, 3

[1] 1 = Inadequate bait acceptance because of an abundance of other food.
2 = Partial estivation or hibernation at time of application.
3 = Dense range forage obscured bait.

The duration which residual bait remained in the field was studied by taking measurements periodically at selected localities with the aid of a special 5-ft² counting frame, which could be relocated precisely on the same spot when subsequent counts were made.

Results

The effectiveness of the aerial baiting is given in Table 1. With maximum squirrel activity and good bait acceptance, control was 90% or more with 0.113% 1080 bait applied at rates of 6 lb/swath-acre and above. The rates of 4 and 5 lb were not tested sufficiently to permit any definite conclusion. Though tests were limited, results did not differ significantly when bait containing concentrations varying from 0.070 to 0.113% 1080 was applied at the same rates under similar range conditions or squirrel densities (Table 2). Control was less than desirable on the Newhall property where the low rate of 0.056% was compared with 0.113% 1080; however, poor results were also attributed to other reasons.

The poor results obtained in some tests were believed to be due to inadequate bait acceptance and/or dense herbaceous forage that obscured much of the bait. Additional factors at the time of some treatments were estivation or hibernation by part of the population. Once it was determined that 0.113% bait at 6 lb/swath-acre gave consistently satisfactory control if the treatment was done when the squirrels readily accepted the bait (Tables 1 and 2), the developmental stage was expanded into a limited operational program treating more than 160,000 acres. Because of the size of the acreages involved, there was insufficient time and manpower to evaluate control on all these ranches, so on some of them we had to rely on the ranchers for estimates of the degree of control achieved. With few exceptions the ranchers reported good to excellent squirrel control during all of the operational phase.

Because of the importance of the side effects of pest control programs on certain nontarget species, this aspect was included in the study. Data contributed by personnel of the California Department of Fish and Game indicate that the aerial technique presented minimal hazards, for there were no detectable losses to game birds in any of the areas that were sampled. Jackrabbits (*Lepus californicus*) occasionally consumed a lethal amount, and in certain localized areas the cotton-

Table 2. Percent control (to the nearest whole number) of ground squirrels resulting from two types of aerial application of different concentrations of 1080 applied at comparable rates under similar conditions.

Property	Date of application	Acres treated (gross)	Rate/swath-acre (lb)	Kernels of bait/ (ft²)	1080 (%)	Type of application	Squirrel control (%)	Reasons attributed to reduced control[1]
Fickert	10/64	2,000	14	5.7	0.113	Stripping	86	2
Fickert	10/64	800	14	5.7	0.084	Stripping	86	2
Newhall	6/66	640	4	1.6	0.056	Stripping	71	1, 3
Newhall	6/66	640	4	1.6	0.113	Stripping	68	1, 3
Ketchum	6/66	1,240	6	2.4	0.113	Spot broadcast	92	—
Ketchum	6/66	250	6	2.4	0.070	Spot broadcast	90	—

[1] 1 = Inadequate bait acceptance because of an abundance of other food.
2 = Partial estivation or hibernation at time of application.
3 = Dense range forage obscured bait.

Table 3. Pre-treatment and post-treatment census of deer mice on rangelands where ground squirrels were baited by aircraft.

Property	Pre-treatment			Post-treatment			Reduction (%)
	Date	No. trap-nights	Mice/100 trap-nights	Date	No. trap-nights	Mice/100 trap-nights	
Santa Margarita	9/14/64	300	7.3	10/ 8/64	300	1.3	82
Santa Margarita	9/14/64	300	6.7	10/ 8/64	300	.7	90
Fickert	9/ 7/64	800	.6	9/26/64	900	.1	83
Newhall	7/ 7/65	200	1.5	7/12/65	200	0	100
Newhall	7/ 7/65	200	.5	7/12/65	200	0	100
Newhall (control[1])	7/ 7/65	200	3.5	7/12/65	200	2.5	29[1]
Boswell	7/11/65	150	4.7	7/27/65	150	0	100

[1] This trap line was located in comparable habitat, but no bait was applied in that area.

tail (*Sylvilagus*) populations suffered some loss. Post-treatment searches revealed no evidence that valley quail (*Lophortyx californica*), numerous in the treated areas, were affected by this method of bait application.

Censuses of deer mice (*Peromyscus*), taken before and after the aerial treatment on several ranches, show that the number of deer mice was reduced (Table 3). Some dead kangaroo rats (*Dipodomys*) and wood rats (*Neotoma*) were also found, but the extent of reduction of their population was not determined.

Field tests indicate that cereal baits are removed and consumed by invertebrates, such as harvester ants (*Pogonomyrmex*) and darkling ground beetles of the family Tenebrionidae. A harvester ant may carry off the bait, a kernal at a time, to its nest, as far as 50 ft away. Ultimately, the ant colonies will be poisoned by the sodium fluoroacetate (1080). In contrast, 1080 was not lethal to darkling ground beetles, which fed on treated bait for 4 days in the laboratory without showing ill effects.

To determine the extent that some insects feed on broadcast bait, kernels can be examined for mandible serrations. In one survey, mandible-produced serrations, presumably due to darkling ground beetles or beetles of similar size, were evident on 5.4% of the kernels which could be located 25 days after they had been broadcast. In a 54-day period, small invertebrates removed or consumed 34% of the bait (20 kernels each under 10 wire-mesh cages) located at selected spots on the Santa Margarita ranch. This substantiates what has long been suspected—that invertebrates can play a significant role in the degradation of broadcast cereal baits.

An example of the speed and degree of biological degradation of broadcast baits is indicated in Table 4. Climatic degradation (i.e., rain in combination with other weather factors) is responsible for reducing the residual bait to minute intrinsic parts of the substrate. Residual bait was never recovered after the winter rainy season. Sodium fluoroacetate is highly water-soluble and is leached from the bait by rain, thereby rendering the baits nearly innocuous even before the kernal disintegrates.

Discussion

The use of aircraft to dispense bait to control ground squirrels has many distinct advantages over the hand-baiting methods currently used. The use of aircraft eliminates the necessity of recruiting large—and often inexperienced—seasonal crews to help conduct organized county squirrel control programs, as is done in parts of California. An experienced pilot can usually spot-treat approximately 1 to 2 thousand acres/hour, which means that large acreages can be treated during a short period in late spring or early summer when the annual grasslands are drying up, one of the optimum times of the year for controlling ground squirrels. Aircraft can achieve better coverage, in many cases, because they can cover remote mountain clearings and steep and rocky canyons that are nearly inaccessible by horseback. Squirrel populations in such areas are too often overlooked when baiting is done from horseback. These natural rodent reservoirs can then rapidly reinfest adjoining range where control has been effective.

Table 4. Percentage of aerial-broadcast bait remaining for various periods on ten 5-ft² sites (a total of 50 ft²) on each of three areas on the Santa Margarita Ranch.

Date count made	No. kernels and (%) of initial application		
	Area A	Area B	Area C
6/17/65	125 (100)[1]	137 (100)[1]	
6/18/65	74 (59)	72 (53)	143 (100)[1]
6/21/65	60 (48)	62 (45)	96 (67)
6/25/65	50 (40)	53 (39)	89 (62)
8/10/65	7 (6)	26 (19)	68 (48)
4/20/66	0 (0)	0 (0)	0 (0)

[1] The first counts were made immediately after the application, before squirrels and invertebrates had an opportunity to feed on the bait; thus, this count represents 100% of the initial bait applied at that particular location.

The density at which the kernels are scattered on the ground (deposit pattern) is a prime factor in determining whether the squirrels will find a lethal amount during a single feeding. Actually, if properly applied, very little bait is needed. The narrowest swaths obtainable by the aircraft were used, because narrow swaths produce denser deposit patterns with the same amount of bait, and bait need be applied on only a fraction of the squirrel-infested area. Swaths 30 ft wide controlled squirrels effectively. To make wider swaths and still obtain the desired deposit pattern, the total amount of bait used per acre would have to be increased, which would increase the cost of the operation and the hazards to nontarget species.

The four fixed-wing aircraft and one helicopter used in the experiments were rented on an hourly basis. The cost, including wages of the pilot, varied from $45.00 to $100.00/hr (in 1964–1966), depending on the type of craft. Helicopters are the most expensive, but their greater maneuverability and efficiency provide partial compensation. The success of any control operation is affected significantly by the ability of the pilot to distribute baits properly. Strip baiting requires less ability from the pilot, and it is the most suitable method on rangeland that is uniformly infested with a dense population of squirrels.

Spot broadcasting requires that the pilot be sufficiently trained and experienced to recognize squirrel colonies and typical squirrel habitat from the air, thus enabling him to place bait reasonably close to the burrows. In certain types of terrain it is amazingly easy to recognize squirrel colonies even from altitudes of several hundred feet. Although it might appear from the data that spot broadcasting gave better results than strip baiting, we do not believe such to be the case. These differences in control success are attributed to other causes.

Crimped oat groats were selected as the bait material best satisfying the desired qualities of a squirrel bait. Groats require less toxicant and can be consumed more rapidly by squirrels than grains with hulls still on. Since effective control of squirrels is usually achieved within a few days of treatment, any biological or climatic degradation of bait during the drier season does not interfere with control. In fact, it is desirable that residual bait soon disappear from the environment.

Sodium fluoroacetate (1080) is preferred over other rodenticides because of its effectiveness. The use or supervision of use of 1080 for field rodent control is restricted by law to governmental agencies, which places the responsibility for aerial baiting in the hands of trained individuals. In California, laws and regulations governing the use of 1080 and aerial applications by commercial operators of all rodenticides provide safeguards against indiscriminate aerial application of ground squirrel baits. The concept of aerial baiting of ground squirrels will become increasingly valuable as new and more selective rodenticides are developed.

Conclusions

The use of aircraft to disseminate grain baits to control ground squirrels (*Citellus beecheyi*) has proven to be effective after three years of development and evaluation. Aerial baiting takes advantage of the foraging ability of squirrels to locate and consume a fatal amount of widely scattered broadcast bait. Crimped oat groats treated with 0.070 to 0.113% sodium fluoroacetate (1080) at 6 lb/swath-acre gave good squirrel control if applied at a time when squirrels were foraging for seed and none were hibernating or estivating. Both strip baiting and spot broadcasting by air gave satisfactory results, using the narrowest swath attainable by the aircraft. Bait need be applied to only a fraction of the ground surface if done at a time of year when the entire squirrel population is active aboveground and foraging extensively for seed.

Other species of rodents are affected by the treatment to varying degrees, but there was no evidence of loss of game birds. Invertebrates and weather are important factors contributing to the degradation of bait.

The aerial technique for applying squirrel baits is being used currently as a control practice in several counties of California, and has recently been used experimentally on rangeland in Nevada. The technique is not a panacea for all squirrel control; rather, it is an advanced method that will be useful in many situations. If used with discretion, aerial baiting is a safe and valuable tool for the control of ground squirrels in western rangeland.

LITERATURE CITED

FITCH, H. S. 1948. Ecology of the California ground squirrel on grazing lands. Amer. Midland Nat. 39:513–596.

HOWARD, W. E., B. L. KAY, J. E. STREET, AND C. F. WALKER. 1956. Range rodent control by plane. Calif. Agr. 10(10): 8–9.

HOWARD, W. E. 1959. How to overcome bait shyness in rodents. Pest Control 8(27):9, 10, and 13.

KALMBACH, E. R. 1943. Birds, rodents and colored lethal baits. N. Amer. Wildl. Conf., Trans. 8:408–415.

MARSH, R. E. 1967. Aircraft as a means of baiting ground squirrels. Proc. Third Vertebrate Pest Conf., San Francisco, Calif., March 7–9, 1967, pp. 2–6. Univ. Calif., Davis. 177 pp.