Efficacy of Zinc Phosphide Broadcast Baiting for Controlling Richardson's Ground Squirrels on Rangeland

G.H. MATSCHKE, M.P. MARSH, AND D.L. OTIS

Abstract

Zinc phosphide, a potential replacement rodenticide for strychnine or 1080, was field tested on 3 populations of Richardson's ground squirrel. Populations were estimated pretreatment and posttreatment by mark-recapture sampling techniques. We broadcasted a 2% zinc phosphide grain bait at 5.1 kg per swath ha. Swath widths measured 6.1 m, 16.0 m of untreated areas remaining between swaths. Treated populations decreased an average of 85.1 ± SE 6.4%. Differences in pretreatment and posttreatment population decline between treated and control populations were significant (P = 0.096). No mortality was detected among nontarget animals. The 85.1% efficacy achieved by broadcast baiting exceeded the minimum standard of 70.0% established by the Environmental Protection Agency for the registration of a rodenticide. Registration, however, will require nontarget hazard testing and further efficacy testing in other geographical locations.

Strychnine and sodium monofluoroacetate (1080) are the only rodenticides currently registered for control of Richardson's ground squirrels *(Spermophilus richardsonii)* and their future remains uncertain. The registration of either could be cancelled because of potential environmental hazards to nontarget species. This potential was determined by the Environmental Protection Agency (EPA) who, following the amendment of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) in 1975, placed both compounds under a Rebuttable Presumption Against Registration.

To find an alternative to these compounds, we began evaluating zinc phosphide. Field tests showed that populations of Richardson's ground squirrels were significantly reduced when we applied by hand a 2% zinc phosphide grain bait adjacent to each burrow entrance (Matschke et al. 1978, Matschke et al. 1979). Because hand baiting at each burrow is labor intensive and expensive (Wood 1965), an alternative method was needed for control of ground squirrels on rangeland.

Several studies indicate that broadcast baiting by ground machinery or aircraft is effective because of the foraging activity of ground squirrels. Marsh (1968) reported a 90% reduction in California ground squirrels *(Spermophilus beecheyi)* with a 0.113% bait applied aerially at 6.7 kg/swath ha. Swath widths measured less than 13.7 m with up to 79.1 m remaining between swaths. Hegdal et al. (1978) reported a 71.7% reduction in California ground squirrel activity (range 34.3–91.0%) when a 0.075% 1080 grain bait was broadcast aerially at 6.7 kg/swath ha. Swath widths measured 12.2 m with up to 60.9 m remaining between swaths. Glahn (ND) reduced California ground squirrel populations along canal banks from 65 to 88% with a 2% zinc phosphide grain bait. The grain was broadcast from the rear of a vehicle at 6.7 kg/ha and at swath widths of 3.0 to 4.6 m. Record (1978) reported reductions in Richardson's ground squirrel populations of from 63 to 97% when strychnine bait was broadcast at 1.36 to 4.54 kg/swath ha at intervals of from 0 to 30.5 m between swaths 6.1 m wide.

We designed the present study to determine if broadcasting a 2% zinc phosphide grain bait with ground-driven machinery would effectively reduce Richardson's ground squirrel populations. The application rate of 6.7 kg/swath ha was adapted from Glahn's (ND) research on California ground squirrels. Lacking adequate movement data, we arbitrarily selected 16.0 m of untreated areas between swaths. Theoretically, foraging ground squirrels would move no more than 8.0 m before encountering bait.

Methods

In June 1980, we established 6 test plots in rangeland pastures in the Shields River Valley (elevation about 1,524 m), Park County, Mont. Treated plots 1, 2, and 3 each consisted of a 1-ha trapping grid staked at 10-m intervals plus a buffer zone for minimizing posttreatment reinvasion by ground squirrels. The 237-m buffer zones of plots 1 and 2 increased the total area of each to 33 ha. An irregularly shaped buffer zone increased plot 3 to only 24 ha. The northern buffer zone of plot 3, reduced by almost half by diagonal fencing, measured 226 m from the NW corner and 132 m from the NE corner of the grid. Livestock were not present on any plot or buffer.

Six nontarget species were observed on the treated plots or their buffers: Long-tailed weasels *(Mustela frenata)* were observed pretreatment and posttreatment on all treated plots. Vesper sparrows *(Pooecetes gramineus)* nested in the buffers on plots 1 and 3. Sage grouse *(Centrocerus urophasianus)* were observed pretreatment in the buffers of plots 1 and 3. One cottontail rabbit (*Sylvilagus* spp.) was observed in the buffer of plot 1. Occasionally pronghorns *(Antilocapra americana)* and marsh hawks *(Circus cyaneus)* were seen in the buffers of treated plots. Coyotes *(Canis latrans)* were observed adjacent to the treated buffers.

We estimated pretreatment and posttreatment ground squirrel populations on each plot, excluding the buffer zones, by using a mark-recapture technique of Otis et al. (1978). We chose to estimate population size with the jackknife estimator, corresponding to their model M_h, because previous extensive analysis of similar ground squirrel trapping data revealed this model to be most appropriate (Matschke et al. 1978). Population estimates were obtained with the computer program entitled CAPTURE (White et al. 1978).

Before the pretreatment and posttreatment trapping periods, we baited traps with wheat and wired them open, allowing the squirrels a 2-day familiarization period. We then trapped for 5 days each pretreatment and posttreatment with 7 days between trapping periods. Squirrels were tagged (Monel #1 fingerling) in each ear and marked with shoe polish to prevent duplicate handling on any one day. Age (juvenile or adult) and sex were recorded before

Authors are wildlife biologist, biological aid, and research statistician, respectively, U.S. Fish and Wildlife Service, Denver Wildlife Research Center, Building 16, Denver Federal Center, Denver, Colorado 80225.

The authors are indebted to D. Decker and L. Lamper, U.S. Fish and Wildlife Service, and to D. Sanchez and R. Dizon, graduate students, Bowling Green State University, Ohio, for their technical assistance.

Manuscript received January 2, 1982.

squirrels were released. Traps were checked each morning and evening and closed at midday to prevent squirrel mortality resulting from heat. We then estimated population reduction for each treated plot by the following formula:

$$\%\text{ Population reduction} = \frac{\text{Pretreatment population estimate} - \text{Posttreatment population estimate}}{\text{Pretreatment population estimate}} \times 100$$

With marked survivors retrapped after treatment, we derived a second population reduction estimate using Tanaka's (1976) formula:

$$\%\text{ Population reduction} = 1 - \frac{\text{Number marked pretreatment and captured posttreatment}}{\text{Number marked pretreatment } (1-(1-\hat{p})^t)} \times 100$$

where $\hat{p}$ estimates the average probability of capturing an animal on one of t pretreatment trapping occasions. Program CAPTURE also provides an estimate of this parameter.

An analysis of variance involving a two-way layout with repeated measures tested treatment by time interaction, i.e., whether changes in pretreatment and posttreatment population sizes on treated plots were related to treatment rather than to natural changes in population levels during the course of the experiment.

Steam-rolled oats from the U.S. Fish and Wildlife Service's Pocatello Supply Depot were used for both prebait and the toxicant carrier. Ingredients added to the oats for baiting treated plots were: 94% technical zinc phosphide (2.0% by weight); Monastral green-B (0.2% by weight), a bird repellent (Pank 1976); and Alcolec-S (1.0% by weight), an adhesive. A placebo bait for the untreated plots was prepared with the same concentrations and ingredients except that zinc phosphide was excluded.

After the pretreatment trapping period, we randomly assigned each plot as either treated or untreated. To insure uniform application, we established 6.1-m swaths, with 27 baiting swaths on each treated plot (including buffer zones) and 5 on each nontreated plot. The center line of each baiting swath was marked with flags. Lines were 22.1 m apart, leaving 16.0 m of untreated area between swaths.

We attached a cyclone seeder (Model M3B400R, The Cyclone Seeder Co., Inc., Urbana, Indiana)[1] to the rear of a 4-wheel drive pickup truck. It was calibrated to dispense grain in 6.1-m swaths at 6.7 kg per swath ha or approximately 22 seeds 1.0 m^2. However, our actual application rate was 5.1 kg. instead of the expected 6.7 kg of bait per swath ha. This reduction was caused by the following: (1) seeds became packed in the hopper when driven over rough ground and (2) the adhesive used to bind the zinc phosphide on the oats also lightly bound adjacent oats. We suspected the problem when baiting the first plot. Rather than change application rate in the middle of the study, we made no further adjustments to the seeder.

We prebaited the 6 study plots, including buffer zones of the treated plots, by broadcasting steam-rolled oats. One treated plot and its buffer and one untreated plot were prebaited during 1 day.

Two days after prebaiting we applied zinc phosphide-treated bait on the treated plots and their buffers and placebo bait on untreated plots. Baiting began in mid-morning, after dew evaporated, and continued until one treated plot and its buffer and one untreated plot were treated for that day. Treatment day was considered day 0.

On day 1 posttreatment, a systematic search for carcasses began on the 6 plots and adjacent areas and continued through day 4. We collected, froze, and later analyzed stomach samples of ground squirrels and all nontarget animals found dead. The Section of Supporting Sciences, Denver Wildlife Research Center, analyzed the carcasses following the procedure described by Okuno et al. (1975).

Results

Pretreatment and posttreatment population estimates included both adult and juvenile ground squirrels (Fig. 1). On untreated plots no significant difference (paired $t = 0.82$, d.f. $= 2$, $p = 0.49$) occurred between pretreatment and posttreatment population levels. Therefore, we did not adjust estimates of reduction on treated plots for changes in population size on untreated plots. The 2% zinc phosphide treatment reduced the estimated pretreatment population by an average of 85.1 ± SE 6.4%. Estimated reductions on plots 1, 2, and 3 were 73.0, 94.9, and 87.3%, respectively. The test for treatment by time interaction ($F_{1,2} = 4.70$, $P = 0.096$) provided evidence that changes on treated plots differed from those on untreated plots (Fig. 1). Even with small numbers of replications, we believe this test provides evidence that the treatment significantly reduced populations.

Only 16 (7.3%) ground squirrels marked pretreatment were retrapped posttreatment: 11, 0, and 5 on treated plots 1, 2, and 3, respectively. With these data incorporated into Tanaka's formula, we obtained a mean population reduction of 89.0 ± SE 6.7%. This figure was not significantly different from the first estimate of 85.1% ($\chi = 0.19$, d.f. $= 1$, $P = 0.5$). On the 3 control plots we retrapped 273 (71.0%) marked squirrels posttreatment.

A significant ($\chi_2 = 5.5$, d.f. $= 1$, $P < 0.02$) sex ratio shift occurred posttreatment on the 3 treated plots. The male:female ratio (males:100 females) increased from 64:100 pretreatment to 189:100 posttreatment. On the 3 untreated plots, no significant difference ($P = 0.84$) occurred in the sex ratio before and after, 73:100 and 78:100, respectively, on the 3 untreated plots. The sex ratios between the treated (64:100) and untreated plots (73:100) were not significant ($P = 0.52$) before treatment.

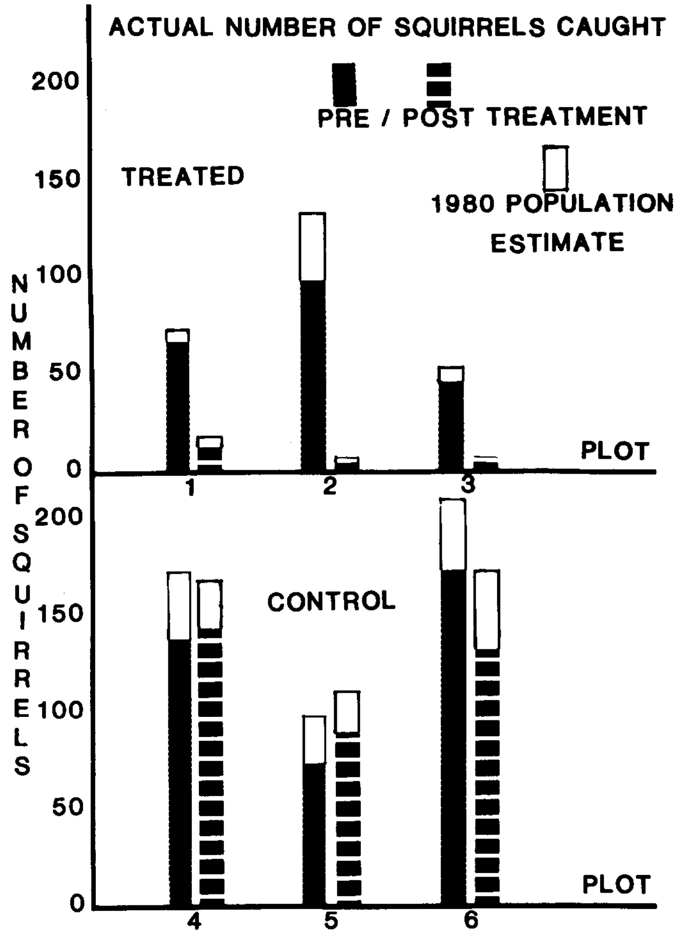

Fig. 1. *Squirrels captured and population estimates on treated and control plots before and after broadcast application of zinc phosphide during July 1980. The solid or broken portion of the bar indicates the number of different ground squirrels captured. The total bar including the open portion provides a population estimate.*

[1]Reference to trade names does not imply endorsement by the U.S. Government.

The 14 ground squirrels found dead posttreatment on the 3 treated plots or their buffers were saved for residue analysis. All were positive for zinc phosphide. Zinc phosphide remaining in the stomach averaged 124.1 ppm, ranging from 0.12–599 ppm. These figures compare with less than 0.04 ppm in the stomachs of the 3 squirrels we collected outside the test plots immediately after the posttreatment trapping period.

No nontarget animals were found dead after a 22.3-hour posttreatment search on the 3 treated plots and their buffers.

Discussion

We believe that 85.1% population decrease accurately reflects the fate of ground squirrel populations following broadcast baiting of a 2% zinc phosphide bait. Posttreatment reinvasion raises the posttreatment population estimate and consequently reduces the percent population reduction. Reinvasion in this study was reduced by (1) an increased buffer width of 237 m and (2) scarcity of juvenile squirrels, which normally make up the bulk of the population after June. Tanaka's estimate of 89.1 ± 6.4% population reduction also supports the population decline. Basically Tanaka's formula uses only marked squirrels that are recaptured posttreatment. Therefore, population reduction estimates are unaffected by unmarked invaders.

Two differences between this study and our 3 previous handbaiting studies were evident (Matschke et al. 1978, Matschke et al. 1979). First, it was difficult to locate the broadcasted treated grain 3-4 days posttreatment, whereas after handbaiting, much treated grain remained at inactive burrows. A second difference was that only 9 marked squirrels (4.1% of the marked squirrels on the treated plots) died above ground compared with 34 (16.4%), 447 (32.1%), and 162 (37.9%) dying above ground in our 3 previous studies. Timing of application may influence above-ground mortality. In the present study we postponed baiting until midmorning. We hypothesize that delayed baiting and activity on the plot probably interrupted the squirrels' morning feeding period and prevented them from consuming a lethal dose until the afternoon feeding period. After feeding they returned to their burrows for the evening and died underground. Our data for above-ground mortality after hand-baiting suggest that more carcasses are found above ground when the bait is applied early in the morning. The number of carcasses above ground declined when bait was applied in late morning or early afternoon.

Determining optimum buffer strip width is a major problem in evaluating efficacy of rodenticides in Richardson's ground squirrel populations. Small buffer strips of 30.5, 61.0, and 85.4 m have not prevented the movement of unmarked squirrels onto the treated plots during the posttreatment trapping periods (Matschke et al. 1978, Matschke et al. 1979). This phenomenon increased population estimates which in turn reduced efficacy estimates. One current buffer width of 235 m appears adequate, since only 10 unmarked squirrels were captured posttreatment on treated plots. But population pressure may not have been sufficient to adequately test the 237-m buffer zone. The squirrel population normally contains a higher percentage of juvenile squirrels after June, as in 1979 when they accounted for 68% of the trapped population (Matschke et al. 1979). In 1980, however, in the same general area and habitat, we trapped only 36% juveniles.

No mortality occurred among nontarget animals. This indicates that broadcast baiting does not affect nontarget species or small numbers of nontarget species may have died and their carcasses were overlooked or removed by scavengers. Also, mortality may have occurred outside the boundaries of the searched areas. To measure the primary and secondary poisoning potential to nontarget species, radio transmitters could be used for tracking pretreatment and posttreatment movement of nontarget species.

Because the 85.1% efficacy exceeded the minimum standard of 70.0% established by the EPA for registering a rodenticide, we believe that broadcasting a 2% zinc phosphide grain bait has management potential. Securing an EPA registration label for broadcast baiting would require efficacy testing in other geographical locations within the range of the Richardson's ground squirrel. Other testing to determine whether efficacy could be increased by manipulation of application rates, swath widths, and swath spacing is also desirable. Also a comprehensive nontarget hazard test would determine the primary poisoning hazards to seed-eating birds. Data on general environmental chemistry and on hazards to humans and domestic animals have been previously supplied to EPA to support 2 of our other zinc phosphide registration labels.

Literature Cited

Glahn, J.F. ND. Application for registration of a zinc phosphide bait for controlling California ground squirrels. Vol. II-Efficacy. Submitted to EPA.

Hegdal, P.L., T.A. Gatz, K.A. Fagerstone, J.F. Glahn, and G.H. Matschke. 1978. Hazards to rabbits, seedeating birds, mammalian predators and raptors associated with 1080 baiting for California ground squirrels. EPA report under Interagency Agreement EPA-IAG-D4-0449.

Marsh, R.E. 1968. An aerial method of dispensing ground squirrel bait. J. Range Manage. 21:380-384.

Matschke, G.H., K.A. Fagerstone, N. Halstead, G.K. LaVoie, and D.L. Otis. 1978. Population reduction of Richardson's ground squirrels using zinc phosphide bait. Job Completion Report for EPA Experimental Use Permit No. 6704-EUP-13, Kremmling, Colo.

Matschke, G.H., K.A. Fagerstone, Hegdal, P.L., and D.L. Otis. 1979. Population control of Richardson's ground squirrels using a 2-percent zinc phosphide bait. Job Completion Report for EPA Experimental Use Permit No. 6704-EUP-13, Park County, Mont.

Okuno, I., R.A. Wilson, and R.E. White. 1975. Determination of zinc phosphide in range vegetation by gas chromatograph. Bull. Environ. Contam. Toxicol. 13:392-396.

Otis, D.L., K.P. Burnham, G.C. White, and D.R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildl. Monogr. 62.

Pank, L.F. 1976. Effects of seed and background colors on seed acceptance by birds. J. Wildl. Manage. 40:769-774.

Record, C.R. 1978. Ground squirrel and prairie dog control in Montana. Proc. Vertebr. Pest Conf. 8:93-97.

Tanaka, R. 1976. Methods of assessing small rodent populations. p. 11-19 *In:* Asian rats and their control. Food and Fertilizer Technology Center for the Asian and Pacific Region. Taiwan.

White, G.C., K.P. Burnham, D.L. Otis, and D.R. Anderson. 1978. User's manual for program CAPTURE. Utah State Univ. Press, Logan.

Wood, J.E. 1965. Response of rodent populations to controls. J. Wildl. Manage. 29:425-437.