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Daniel W. Uresk
Rocky Mountain Forest and Range Experiment Station, Rapid City, South Dakota

Rudy M. King
Rocky Mountain Forest and Range Experiment Station, Rapid City, South Dakota

Anthony D. Apa
South Dakota School of Mines and Technology

Michele S. Deisch
South Dakota School of Mines and Technology

Raymond L. Linder
South Dakota Cooperative Fish and Wildlife Research Unit, South Dakota State University - Brookings

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Rodenticidal Effects of Zinc Phosphide and Strychnine on Nontarget Species[1]

Daniel W. Uresk, Rudy M. King, Anthony D. Apa, Michele S. Deisch, and Raymond L. Linder[2]

Abstract.--When three rodenticide treatments--zinc phosphide (prebaited) and strychnine (both with and without prebait)--were evaluated, zinc phosphide was the most effective in reducing active burrows of prairie dogs; but, it also resulted in a reduction in deer mouse densities. One month after treatment, counts of fecal pellets of eastern cottontails were greater on areas treated with strychnine without prebait than on sites treated with zinc phosphide. Eight months after treatment, no differences could be detected among rodenticides for either leporid. Horned lark densities were reduced 61% on sites treated with strychnine only.

INTRODUCTION

Rodenticides have been used for prairie dog control on the Great Plains since the late 1800's (Merriam 1902). Most recent prairie dog control programs on federal, state, and private lands consist of poisoning prairie dogs with zinc phosphide on rolled oats after prebaiting with rolled oats (Schenbeck 1982). However, for more than 70 years, little effort has been made to evaluate rodenticide impacts on nontarget animals. Recently there has been some concern about the effects of zinc phosphide on nontarget animals. Bell and Dimmick (1975) reported that zinc phosphide was not hazardous to red fox (*Vulpes fulva*), gray fox (*Urocyon cinereoargenteus*), or great horned owls (*Bubo virginianus*). Kit fox (*Vulpes macrotis*) survived after feedings on kangaroo rats (*Dipodomys* sp.) killed with zinc phosphide (Schitoskey 1975). Matschke et al. (1983) reported no mortality among nontarget animals when zinc phosphide-treated grain bait was broadcast to control Richardson's ground squirrels (*Spermophilus richardsonii*).

Strychnine, used for prairie dog control since the late 1800's (Merriam 1902), has been reported to present secondary hazards to nontarget animals (Schitoskey 1975, Hegdal et al. 1981). Wood (1965) reported that densities of five rodent species fluctuated independently over a 2-year period after an area was poisoned with strychnine-treated oats. Birds were killed by surface application of steam-rolled oats treated with strychnine for control of Richardson's ground squirrels (Hegdal and Gatz 1977). No detrimental effects were observed on other rodents or mammalian predators.

To augment the limited information, this investigation was undertaken to compare zinc phosphide and strychnine for effects on nontarget small mammals and birds.

STUDY AREA

The study area was approximately 13 km south of Wall on the Buffalo Gap National Grasslands and Badlands National Park in west-central South Dakota. Climate was semiarid-continental and was characterized by cold winters and hot summers. The average annual precipitation, based on climatological information over a 12-year period (1972-1983) from the weather station at Cedar Pass Visitor Center, Badlands National Park, was 40 cm. Most precipitation fell during the growing season as high-intensity thundershowers, which produced a wide range of amounts and intensities of rain for any given location. The mean annual temperature was 10 °C, ranging from -5 °C in January to 26 °C in July.

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[2]Uresk and King are Research Biologist and Biometrician, respectively, with the Rocky Mountain Forest and Range Experiment Station, Rapid City, S. Dak., in cooperation with the South Dakota School of Mines and Technology; the Station's headquarters is in Fort Collins, in cooperation with Colorado State University. Apa and Deisch were graduate research assistants, and Linder, now retired, formerly Unit Leader, South Dakota Cooperative Fish and Wildlife Research Unit, South Dakota State University, Brookings. Partial funding of this study was provided by National Agricultural Pesticide Impact Assessment Program (NAPIAP).

Soils developed primarily from sedimentary deposits of clay, silt, gravel, and volcanic ash (Raymond and King 1976). Steep gullies, sharp ridges, flat-topped buttes, pinnacles that are partly covered with vegetation, and upland grasslands characterize much of the landscape in the Badlands. Gently sloping grasslands on the National Grasslands made up the major portion of the study area.

The dominant grasses were blue grama (Bouteloua gracilis), buffalograss (Buchloe dactyloides), needleleaf sedge (Carex eleocharis), and western wheatgrass (Agropyron smithii). Scarlet globemallow (Sphaeralcea coccinea), prostrate bigbract verbena (Verbena bracteata), Patagonia Indianwheat (Plantago patagonica), and prairie dogweed (Dyssodia papposa) were the major forbs.

The Badlands National Park area was grazed by bison (Bison bison), pronghorn (Antilocapra americana), and mule deer (Odocoileus hemionus) throughout the year. Cattle on the National Grasslands grazed the area from mid-May to the last of October each year. Stocking levels varied depending upon moisture and available forage. Pronghorn and mule deer grazed the grasslands throughout the year.

METHODS

Eighteen study sites were established on 15 prairie dog colonies that ranged in area from approximately 12 ha to 283 ha. Nine sites were untreated and 9 sites were treated with the rodenticides zinc phosphide (prebaited) and strychnine, with and without prebaiting; thus, each rodenticide treatment had 3 control and 3 treated sites. The 3 rodenticide treatments were clustered into 3 separate groups in an attempt to minimize the possibility that a nontarget animal would be exposed to more than one rodenticide. Clusters were approximately 13 and 16 km apart. Zinc phosphide treatments were applied to sites in the Badlands National Park because of administration constraints against the use of strychnine in such areas. The other 2 treatment groups, strychnine with and without prebaiting with steam-rolled oats, were assigned randomly to the 2 remaining clusters on the National Grasslands.

Steam-rolled oats from the U.S. Fish and Wildlife Service's Pocatello Supply Depot were used for both prebait and carrier. A 2.0% by weight active zinc phosphide and 1.5% Alcolec S[3] adhesive were applied to the oats. Strychnine alkaloid was applied to the oats as 0.5% by weight. Nontreated oats were applied as prebait for zinc phosphide and for 1 of the strychnine treatments during September 20-21, 1983, on prairie dog colonies (Uresk et al. 1986). Active rodenticides on steam-rolled oats were applied during September 22-24, 1983. These rodenticide treatments resulted in active prairie dog burrows being reduced 95% with zinc phosphide, 83% with strychnine (prebaited), and 45% with strychnine only (Uresk et al. 1986).

Pretreatment counts for small mammals and birds were taken on all sites 1 week before application of rodenticides. Posttreatment sampling on all sites began on the fourth day after rodenticides were applied.

Small rodents were sampled on each of the 18 sites before and after treatment. Sixty-four Sherman live traps (23 x 9 cm) were arranged within a grid design with 10-m spacings on each site. Each trap session consisted of 1 night of prebaiting followed by 4 consecutive nights of trapping. All traps were examined for mammals each morning. Traps closed by prairie dogs through the day were reopened in the late afternoon on all sites. A mixture of peanut butter and rolled oats was used for bait in the batting-lined traps. Heavy wire was placed over each trap and inserted into the ground, to reduce disturbance by weather, large herbivores, and prairie dogs. Captured rodents were identified as to species and assigned a unique number by toe amputation. Relative density estimates were obtained as the number of unique animals captured on each site by trap session.

Fecal pellets were used as an index of abundance for the eastern cottontail (Sylvilagus floridanus) and white-tailed jackrabbit (Lepus townsendii) on all 18 sites (Overton 1971). Thirty 1-m^2 circular plots, spaced 30 m apart, were permanently established along transects (0.8 km) on each site. Fecal pellets were collected pre- and post-rodenticide treatment 1 month and 8 months following treatment. Data were analyzed as mean number of pellets per site.

Avian populations were counted on the 18 study sites by using a modified transect method (Emlen 1971, 1977; Rotenberry 1982). Eighteen permanent strip transects, 1 per site, 805 m long and 61 m wide (approximately 4.9 ha), were established. Surveys were conducted on 4 consecutive days before and after rodenticide treatment in a different site order each day. Survey teams started one-half hour after sunrise and continued for approximately 4-5 hours; average walking time was 25-40 minutes per transect. All birds within each transect were identified visually or by vocalization, including birds flying through the transect during the census. Data were averaged over the 4 days by species, and mean numbers of birds per site were used in statistical analyses.

STATISTICAL EVALUATION

The approach chosen to assess the effect of each rodenticide was to compare the change between pretreatment and posttreatment observations on each

[3]The use of the name Alcolec S (American Lecithin Co., Inc.) is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

treated group (cluster) of sites with the change observed on the respective control sites. When a significant correlation existed between pretreatment and posttreatment observations, analysis of covariance was used to estimate change as the posttreatment observation adjusted for the amount by which the pretreatment observation differed from the pretreatment mean. That is,

$$Z_{ij} = Y_{ij} - b(X_{ij} - X)$$

where Z_{ij} is the adjusted observation for the j-th site in the i-th treatment group, Y_{ij} is the posttreatment observation, X_{ij} is the pretreatment observation, X is the mean of pretreatment observations, and b is the regression coefficient. If correlation between pretreatment and posttreatment observations was nonsignificant, change was estimated simply as

$$Z_{ij} = Y_{ij} - X_{ij}$$

and the analysis was based on an interaction between time and treatment as the indicator of a significant change due to treatment (Green 1979). Unless indicated otherwise, the statistical package for the social sciences (SPSS) was used to produce the statistical calculations (Nie et al. 1975, Hull and Nie 1981).

Once the form of the change variable (Z_{ij}) was chosen, contrasts between treated and respective control groups were formed as $C_1 = Z_1 - Z_2$, $C_2 = Z_3 - Z_4$, and $C_3 = Z_5 - Z_6$, where Z_1 represents the estimated average change on the zinc phosphide sites, Z_2 the estimated average change on the respective control sites, and so on for the prebaited strychnine and strychnine only treatments. If significant individual treatments effects were observed, comparisons among the rodenticides were produced by forming the contrasts $C_4 = C_1 - C_2$, $C_5 = C_1 - C_3$, and $C_6 = C_2 - C_3$.

Randomization procedures were used to estimate the statistical significance of the various contrasts (Edgington 1980, Romesburg 1981). These procedures do not rely on the normality assumption inherent in standard analysis of variance testing techniques; rather, they provide a general framework incorporating separate but similar analyses depending on the outcome of tests for significant correlation between pretreatment and posttreatment observations, common regression slopes among treatment groups, and homogeneous variance among treatment groups. A test statistic, $t = C_i/\text{Sqrt}[\text{Var } C_i]$, was computed for each contrast (C_i) and significance level estimated using randomization procedures based on 10,000 random permutations of the data pairs (X_{ij}, Y_{ij}) among the treatment groups. Variance of a contrast was computed as the sum of the variances of the means in the contrast, with individual variances computed based on the covariance and homogeneous variance assumptions appropriate for the particular variable.

Because omission of any effect due to poisoning, especially for the nontarget species, was considered more serious than the potential incorrect declaration of a significant treatment effect, Type II error protection was produced by testing each contrast individually. However, except when heterogeneous variance was present and therefore no overall test was available, some Type I error protection was afforded by testing individual contrasts only after first observing a significant (P = 0.10) overall test of treatment differences using analysis of variance or covariance (Carmer and Swanson 1973). Individual contrasts were considered biologically significant at P = 0.25. Although admittedly unconventional, for the number of sites available for study, this significance criterion produces a power (probability of detecting a true difference) of approximately 0.75 for a contrast twice as large as its standard error. This was considered a reasonable combination of Type I and Type II error protection for this study (Carmer 1976, Salsburg 1985).

RESULTS

Small Rodents

Six rodent species were captured on the 18 sites: deer mouse (Peromyscus maniculatus), northern grasshopper mouse (Onychomys leucogaster), thirteen-lined ground squirrel (Spermophilus tridecemlineatus), western harvest mouse (Reithrodontomys megalotis), Ords kangaroo rat (Dipodomys ordii), and hispid pocket mouse (Perognathus hispidus). Deer mice were the only rodent captured in sufficient numbers to be used for statistical comparisons; however, no significant reductions (P = 0.363) were observed among treatments. Relative densities of deer mice changed 79% from 5.8 to 1.2 unique animals, following the zinc phosphide treatment (table 1).

Leporids

No differences were found in the adjusted fecal pellet means of the eastern cottontail between control and treated sites for zinc phosphide and strychnine without prebait (P = 0.812 and P = 0.655, respectively, table 2). Areas treated with strychnine (prebait) showed an increase (P = 0.031) in adjusted mean number of fecal pellets. However, no differences were found between treated and control sites for fecal densities 8 months after prairie dogs had been poisoned (table 2).

Higher numbers of fecal pellets of white-tailed jackrabbits were observed (P = 0.088) on the zinc phosphide sites versus control (table 3). No differences in jackrabbit abundance were found between control and treated sites on areas treated with strychnine with (P = 0.725) and without prebaiting (P = 0.683). However, 8 months after rodenticides were applied, whitetail jackrabbit fecal pellet counts were not different between treated and control sites (P = 0.431).

Birds

Application of zinc phosphide for black-tailed prairie dog control did not significantly reduce

Table 1.--Relative densities of deer mice (unique animals/768 trap nights ± standard error) for pretreatment and posttreatment on treated and control sites for each rodenticide. Variances were heterogeneous and pretreatment data were used to adjust posttreatment means by covariance analysis. Adjusted posttreatment data had homogeneous variances.

Treatment	Pretreatment	Posttreatment	Adjusted effect[1]
Prebait: Zinc phosphide			
Treated	8.3 ± 2.6	1.3 ± 0.7	
Control	4.0 ± 2.0	2.3 ± 0.9	-4.6 ± 2.7
Strychnine			
Treated	1.9 ± 1.0	0.7 ± 0.7	
Control	9.0 ± 3.2	7.0 ± 4.0	0.3 ± 2.7
Prebait: Strychnine			
Treated	8.7 ± 1.5	3.7 ± 1.9	
Control	18.0 ± 3.1	12.3 ± 4.9	-0.9 ± 2.7

[1]Adjusted effects were not significant (P = 0.363); therefore, statistical significance of contrasts was not determined.

Table 2.--Average pellet counts (mean/30 m^2 ± standard error) of eastern cottontail for pretreatment and posttreatment on treated and control sites for each rodenticide. Variances were homogeneous and pretreatment data were used as covariate to adjust posttreatment means.

Treatment	Pretreatment	Posttreatment	Adjusted effect[1]	Significance level (control vs. treated)[1]	Adjusted effect 8 mo. after treatment[2]
Prebait:Zinc phosphide					
Treated	17 ± 6	8 ± 7			
Control	158 ± 133	32 ± 30	3.9 ± 13.1[1]	0.812	-4.6 ± 13.9
Strychnine					
Treated	31 ± 13	16 ± 15			
Control	183 ± 109	54 ± 19	-7.5 ± 13.1	0.655	20.2 ± 13.9
Prebait:Strychnine					
Treated	102 ± 22	25 ± 14			
Control	296 ± 97	30 ± 16	34.0 ± 13.4	0.031	15.1 ± 13.9

[1]Randomization test used for testing differences between pairs of adjusted means.
[2]Adjusted effects were not significant (P = 0.260); therefore, statistical significance of contrasts was not evaluated.

Table 3.--Average pellet counts (mean/30 m^2 ± standard error) of white-tailed jackrabbits for pretreatment and posttreatment on treated and control sites for each rodenticide.

Treatment	Pretreatment	Posttreatment	Adjusted effect[1]	Significance level (control vs. treated)[2]	Adjusted effect 8 mo. after treatment[3]
Prebait:Zinc phosphide					
Treated	9 ± 7	43 ± 31			
Control	72 ± 40	16 ± 12	90.4 ± 46.3	0.088	70.0 ± 41.6
Strychnine					
Treated	11 ± 2	5 ± 2			
Control	24 ± 18	22 ± 12	-5.0 ± 9.0	0.683	18.7 ± 41.6
Prebait:Strychnine					
Treated	34 ± 24	42 ± 17			
Control	69 ± 58	49 ± 8	28.0 ± 60.1	0.725	37.7 ± 41.6

[1]Posttreatment minus pretreatment was used to adjust data since covariance model was not significant (P = 0.502) and variances were heterogeneous.
[2]Randomization test used for testing differences between pairs of adjusted means.
[3]Posttreatment minus pretreatment was used to adjust data since covariance model was not significant (P = 0.450). Adjusted effects were not significant (P = 0.431); therefore, statistical significance of contrasts was not evaluated.

numbers of horned lark (Eremophilia alpestris) (P = 0.974, table 4). When strychnine was applied without prebait, horned larks were significantly reduced (P = 0.114). Strychnine with prebaiting also had apparent effects on horned lark densities (P = 0.124). Comparisons among rodenticides showed no differences with zinc phosphide compared to strychnine only and strychnine with prebait, P = 0.256 and P = 0.267, respectively. Strychnine comparisons were not different (P = 0.964).

Because individual bird species densities were highly variable, 15 species of birds were grouped to determine treatment effects among rodenticides (table 5). Overall test among treatments was significant (P = 0.025). Ground feeding birds showed no differences between control and treated sites in adjusted relative densities on zinc phosphide (P = 0.431), prebaited strychnine (P = 0.360), and strychnine (P = 0.364) treatment areas. A comparison among rodenticides showed differences between zinc phosphide with strychnine (P = 0.228), and zinc phosphide with prebait strychnine (P = 0.223). Higher densities of birds were observed on the zinc phosphide-treated sites.

DISCUSSIONS AND CONCLUSIONS

Zinc phosphide as a prairie dog control agent, was associated with reduced densities (79%) of deer mouse, a nontarget species; however, the effect was

Table 4.--Relative densities of horned lark (mean number/4.9 ha ± standard error) for pretreatment and posttreatment on treated and control sites for each rodenticide. Pretreatment data were different (P = 0.043) among rodenticides, and analysis was conducted on posttreatment minus pretreatment data.

Treatment	Pretreatment	Posttreatment	Adjusted effect	Significance level (control vs. treated)[1]
Prebait: Zinc phosphide				
Treated	17 ± 6	22 ± 7		
Control	12 ± 5	21 ± 8	0.3 ± 9.3	0.974
Strychnine				
Treated	12 ± 9	2 ± 1		
Control	22 ± 12	17 ± 8	-15.2 ± 9.3	0.114
Prebait: Strychnine				
Treated	30 ± 8	6 ± 3		
Control	67 ± 20	20 ± 2	-14.6 ± 9.3	0.124

[1]Randomization test used for testing differences between pairs of adjusted means.

Table 5.--Relative densities of total ground-feeding birds (mean number/4.9 ha ± standard error) for pretreatment and posttreatment on treated and control site for each rodenticide. Correlation was not significant (P = 0.248). Analysis was conducted on posttreatment minus pretreatment data.[1]

Treatment	Pretreatment	Posttreatment	Adjusted effect	Significance level (control vs. treated)[2]
Prebait: Zinc phosphide				
Treated	31 ± 6	53 ± 12		
Control	24 ± 8	38 ± 16	15.0 ± 12.9	0.431
Strychnine				
Treated	18 ± 12	4 ± 2		
Control	25 ± 13	20 ± 10	-16.9 ± 12.9	0.364
Prebait: Strychnine				
Treated	31 ± 8	7 ± 2		
Control	72 ± 18	24 ± 4	-17.2 ± 12.9	0.360

[1]Avian species that showed no differences individually or grouped: Sharp-tailed Grouse (Tympanuchus phasianellus), Killdeer (Charadrius vociferus), Mourning Dove (Zenaida macroura), Northern Flicker (Colaptes auratus), Says Phoebe (Sayornis phoebe), Black-billed Magpie (Pica pica), American Crow (Corvus brachyrhynchos), Mountain Bluebird (Sialia currucoides), American Robin (Turdus migratorius), Water Pipit (Anthus spinoletta) migrant, European Starling (Sturnus vulgaris), Vesper Sparrow (Pooecetes gramineus), Savannah Sparrow (Passerculus sandwichensis), Chestnut-collared Longspur (Calcarius ornatus), Western Meadowlark (Sturnella neglecta).

[2]Randomization test used for testing differences between pairs of adjusted means.

not statistically significant because of high variability in densities. Strychnine with or without prebait was not associated with significant reductions in deer mouse densities. This finding is contrary to the 86% reduction in rodent populations reported by Wood (1965) 1 month after treatment with strychnine.

Pellet counts have been used to measure relative abundance of rabbit numbers in various habitats (Vorhies and Taylor 1933; Arnold and Reynolds 1943; Westoby and Wagner 1973; MacCracken and Hansen 1982). Conde (1982) compared the abundance of pygmy rabbits (Sylvilagus idahoensis) and black-tailed jackrabbits (Lepus californicus) by strip census with fecal pellet counts and showed a good correlation between the 2 methods. In this study, eastern cottontail fecal pellet counts after treatment were greater on strychnine-prebaited sites than on other treated sites. This may be attributable to the slightly rougher terrain of the strychnine area, offering a more suitable habitat for cottontails (Flinders and Hansen 1975). However, 8 months after treatment in this study, eastern cottontails showed no differences among rodenticide treatments. White-tailed jackrabbit abundance was higher on areas treated with zinc phosphide immediately after treatment. This flat and open area is preferred by the white-tailed jackrabbits. In addition, western wheatgrass, a major food item of white-tailed jackrabbits, was more abundant on zinc phosphide sites compared to the other rodenticide-treated areas (Flinders 1971). Eight months later, in our study, white-tailed jackrabbit abundance was not different among rodenticide treatments. The 3 rodenticides did not negatively affect either eastern cottontails or white-tailed jackrabbits.

Effect of strychnine on some bird species has been documented by several investigators. Rudd and Genelly (1956) stated that hazards of strychnine application in the field were much higher for waterfowl than for upland game birds such as Gray partridge (Perdix perdix), ring-necked pheasant (Phasianus colchicus), quail (Odontophorinae), sharp-tailed grouse (Tympanuchus phasianellus), and prairie chicken (Tympanuchus sp.). Hegdal and Gatz (1977) reported that there was a significant hazard to some seed-eating birds, which included horned larks, mourning doves (Zenaida macroura), and blackbirds (Emberizinae). They also stated that vesper sparrows (Pooecetes gramineus) and western meadowlarks (Sturnella neglecta) were affected but to a lesser extent. Tietjen (1976) and Matschke et al. (1983) reported no significant mortality for nontarget seed-eating birds with application of zinc phosphide, but additional tests were recommended.

Horned larks in this study decreased in relative density on areas treated with strychnine and prebait strychnine. However, zinc phosphide showed no effects. The time of rodenticide application during the fall could have influenced the number and species of birds affected. Weather conditions can affect the movements of migrant birds as well as resident birds during the time when rodenticides are applied. Ground-feeding birds individually or as a group excluding horned larks showed no response to the 3 rodenticide treatments. Many of the ground-feeding birds were beginning to group in certain areas because of inclement weather during post-treatment measurements. This increased variability between and among sites may have contributed to the lack of significant effects of rodenticide treatment for ground-feeding birds as a group. A comparison of rodenticides showed greater effects on birds with both strychnine treatments and less with zinc phosphide.

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