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IMPACTS OF BLACK-TAILED PRAIRIE DOG RODENTICIDES ON NONTARGET PASSERINES

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ABSTRACT.—In 1983 zinc phosphide, strychnine with prebait, and strychnine without prebait were applied to black-tailed prairie dog (*Cynomys ludovicianus*) colonies in west central South Dakota. Short-term (four days later) and long-term (one year later) impacts of the rodenticides on Horned Larks (*Eremophila alpestris*) and other granivorous birds inhabiting prairie dog colonies were evaluated. Horned Larks and 49 other bird species were observed. Immediate impacts reduced Horned Lark relative densities 66% with strychnine only and 55% with prebaited strychnine. Zing phosphide caused no measurable reduction. Horned Larks showed no long-term direct impacts. Indirect negative impacts occurred through habitat changes following prairie dog control. The granivorous guild showed no short- or long-term effects.

Key words: Cynomys ludovicianus, Eremophila alpestris, *granivorous guild, zinc phosphide, strychnine.*

Poisons applied to oats are the past and present primary tool for black-tailed prairie dog (*Cynomys ludovicianus*) control. Strychnine was introduced into the United States about 1847, and its success as a rodenticide has varied (Crabtree 1962). The alkaloid form on grain was recommended by the U.S. Department of Agriculture at the beginning of the century (Merriam 1902, Crabtree 1962). Inconsistent treatment effects in certain situations and potential hazards to many nontarget species (Tietjen 1976) have caused concern.

Zinc phosphide was introduced as a vertebrate pest control agent in 1943 due to strychnine shortages during World War II (Crabtree 1962). Following replenished supplies of strychnine and the development of sodium monofluoracetate (Compound 1080), use of zinc phosphide as a field rodenticide was curtailed until it was developed specifically for black-tailed prairie dog control in 1976 (Tietjen 1976). Since 1976, zinc phosphide has been the only rodenticide available for prairie dog control when there is federal involvement.

Several granivorous passerines inhabit black-tailed prairie dog colonies (Agnew et al. 1986). Birds residing on prairie dog colonies that could suffer death or illness from poison consumption are those of seed-eating guilds (Root 1967, Creighton 1974.) This guild could consume treated grains. Tietjen (1976) observed Horned Larks (*Eremophila alpestris*) and Mourning Doves (*Zenaida macroura*) on zinc phosphide-treated prairie dog colonies, but observations after treatment did not locate any sick or dead birds. In contrast, Hegdal and Gatz (1977a) found significant mortality of nontarget seed-eating birds, especially Horned Larks and Mourning Doves, when strychnine-treated grain was applied to Richardson's ground squirrel (*Spermophilus richardsonii*)

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colonies. The U.S. Department of Interior (1956) acknowledged that nontarget losses occurred following exposure to strychnine and recommended that attempts be made to minimize the effects.

Quantitative estimates that evaluate poison impacts on avian residents from prairie dog control have not been fully documented. The objectives of this study were to evaluate (1) short- and long-term effects of zinc phosphide (with prebait), strychnine with prebait, and strychnine without prebait on Horned Larks and the granivorous avian guild and (2) compare three rodenticide treatments. Immediate effects on birds by the three rodenticide treatments have been reported by Uresk et al. (1988).

STUDY AREA

The study area is located on Badlands National Park and Buffalo Gap National Grasslands in west central South Dakota. Climate is considered semiarid with an average annual precipitation of 40 cm at the Cedar Pass Visitors Center, Badlands National Park. Approximately 80% of the precipitation falls as thundershowers during April to September, and rainfall can be localized or cover large areas. Temperatures range from −5 C in January to 43 C in July, with an average annual temperature of 10 C.

Raymond and King (1976) described the soils on the area as sedimentary deposits of clay, silt, gravel, and volcanic ash. Topographic features consist of rugged pinnacles, vegetated table top buttes, creek gullies, and grassland basins. Gently rolling grasslands are located in the northern portion of the study area with elevation ranging from 700 to 1000 m.

The vegetation consists of a mosaic of native grasses, forbs, shrubs, and isolated trees. Dominant grasses include bluegrama (*Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*), needleleaf sedge (*Carex eleocharis*), and western wheatgrass (*Agropyron smithii*). Common forbs include scarlet mallow (*Sphaeralcea coccinea*), American vetch (*Vicia americana*), dogweed (*Dyssodia papposa*), sage (*Salvia reflexa*), and prairie sunflower (*Helianthus petiolaris*). The dominant shrub species is pasture sagebrush (*Artemisia frigida*). Nonnative grasses include cheatgrass (*Bromus tectorum*) and Japanese chess (*B. japonicus*). (Scientific names of plants follow Nickerson et al. 1976 and Van Bruggen 1976.) Native herbivores are black-tailed prairie dog, mule deer (*Odocoileus hemionus*), Rocky Mountain bighorn sheep (*Ovis canadensis*), American bison (*Bison bison*), pronghorn (*Antilocapra americana*), black-tailed jackrabbit (*Lepus californicus*), and white-tailed jackrabbit (*L. townsendii*). Small rodents include deer mouse (*Peromyscus maniculatus*) and grasshopper mouse (*Onychomys leucogaster*). Livestock are not present in the Park, but bison graze all year. Cattle are allowed to graze the National Grasslands six months during the growing season each year.

METHODS

Eighteen sites on 15 prairie dog colonies were sampled in 1983 and 1984 with 9 treatment sites and 9 controls (Uresk et al. 1986). Sites were clustered into three major areas, and each rodenticide treatment had 3 treated and 3 control sites. Zinc phosphide with prebait was applied to the area within Badlands National Park because administrative restraints did not allow the use of strychnine. Four of the zinc phosphide (2 treatment and 2 control) sites were clustered and paired on a prairie dog colony of approximately 600 ha. The remaining treatment prairie dog colony was located northwest of the aforementioned larger colony, and the control colony was northeast of the larger colony in the Buffalo Gap National Grasslands. Strychnine with and without prebait treatment was randomly assigned to the two areas on the National Grasslands. The area with prebaited strychnine was located east and south of Scenic, South Dakota. All strychnine treatment and control sites were on isolated towns ranging from 12 to 283 ha. Within each treatment regime, treatment or control designation was determined randomly except when the National Park Service imposed administrative restrictions.

Avian populations were sampled on 18 permanent 805 × 62-m (4.9 ha) belt transects, one on each site. Relative densities of bird species were estimated using a modification of techniques developed by Emlen (1971, 1977) and Rotenberry (1982). The observer walked the transect line and counted birds up to 31 m on either side of the line. Sampling began one-half hour after sunrise and continued for approximately 4–5 hours; average walking time was 15–25 minutes per transect. Sampling was conducted on four consecutive days for each sampling session. Birds hovering over and/or flying over the transect were tallied. In 1983 four pretreatment sampling sessions, prior to poisoning prairie dogs, were conducted in June, July, August, and early September. The sampling session in early September occurred one week prior to poisoning. The first posttreatment session in late September commenced four days after treatment to evaluate short-term treatment effects. Four posttreatment sampling sessions were conducted in June, July, August, and September of 1984 to evaluate long-term treatment effects.

Bait Formulation and Application

Poison application was in accordance with federal label instructions. The untreated oats (prebait) and the poisoned oats were applied from 3-wheel drive ATVs fitted with bait dispensers (Schenbeck 1982). Smaller acreages were treated by hand using teaspoons (H. P. Tietjen, USFWS, Denver, Colorado, personal communication).

Prebait consisted of four grams of high-quality, untreated, steam-rolled oats applied at each prairie dog burrow. Three sites were prebaited on 20 September 1983 and three on 21 September 1983. A minimum of 95% of the burrows were prebaited. Prebait was applied (<0.01 m^2 area) at edges of prairie dog mounds. Three days after prebait application three sites were treated with 4 g of 2.0% active zinc phosphide steam-rolled oats. On 23 September 1983 three additional sites were treated with 8 g of 0.5% strychnine alkaloid steam-rolled oats per burrow. The last three sites were treated with strychnine oats on 24 September 1983 but were not prebaited.

Statistical Analyses

Analysis of covariance was used to compare each treated group (cluster) of sites with its respective control group. Applications of repeated measures were examined but required constant response through time; i.e., no interaction between time and treatment. These data did not show a constant response through time and had interactions; therefore we used covariance adjustments for individual posttreatment sampling sessions. Pretreatment observations were used as covariates. Effect of rodenticide treatment for each time point was estimated as the covariance-adjusted difference between treated and control sites for each rodenticide. After obtaining an overall rejection of the hypothesis of no treatment effect, contrasts for each rodenticide treatment compared to its control were evaluated for significance based on a variance estimated only from the sites in each cluster (variance was heterogeneous among clusters). If the correlation between pretreatment and posttreatment observations was not significant ($\alpha < 0.20$), then estimates of treatment effects were based on the difference between posttreatment and pretreatment observations (repeated measures). This analysis uses the interaction between time and treatment as the indicator of the significant change due to treatment (Green 1979). Rodenticides were compared by forming pairwise contrasts of the contrasts obtained for the individual rodenticide treatments. Randomization procedures (Edington 1980, Romesburg 1981) based on 10,000 random permutations of the data pairs among treatment groups were used to estimate statistical significance of the various contrasts. Variance of a contrast was calculated as the sum of the variances of the means in the contrast, with calculated individual variances based on the covariance and homogeneous variance assumptions appropriate for the particular variable.

Because omission of any effect due to poisoning 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, some Type I error protection was afforded by testing individual contrasts only after first observing a significant ($P = .10$) overall test of treatment differences using analysis of covariance (Carmer and Swanson 1973). Individual contrasts were considered biologically significant at $P = .20$. 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 0.80 for a contrast twice as large as its standard error. This was considered a reasonable

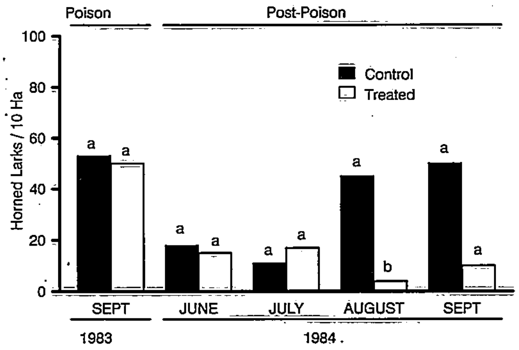

Fig. 1. Seasonal comparisons of Horned Lark relative densities on zinc phosphide–treated and control sites from initial treatment in September 1983 through September 1984. Adjusted means are from covariance analysis. Statistical analysis was conducted on posttreatment minus pretreatment. Means followed by the same letter by date are not significant at $\alpha = 0.20$ after F-protection at $\alpha = 0.10$.

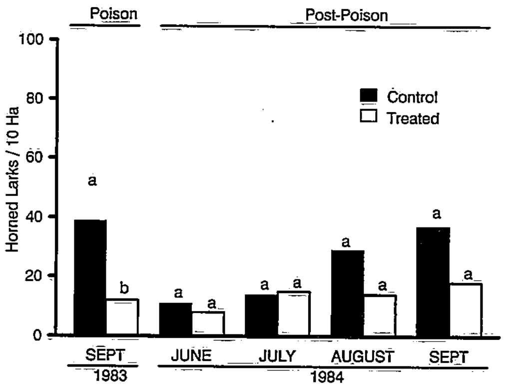

Fig. 2. Seasonal comparisons of Horned Lark relative densities on strychnine-treated and control sites from initial treatment in September 1983 through September 1984. Adjusted means are from covariance analysis. Statistical analysis was conducted on posttreatment minus pretreatment. Means followed by the same letter by date are not significant at $\alpha = 0.20$ after F-protection at $\alpha = 0.10$.

combination of Type I and Type II error protection for this study (Carmer 1976).

RESULTS

Passerines

Forty-six species of birds were observed on all sites in 1983 and 40 in 1984. Eighteen bird species present on the sites were different between years. Total bird observations in 1983 were 8639; 65% of the sample consisted of Horned Larks, and 14% were Western Meadowlarks. However, in 1984 total bird observations were 5965, with Horned Larks accounting for 56% and Western Meadowlarks 18% of the sample. Unidentified species were less than 1% of the sample either year.

Horned Larks

There was no difference ($P = .977$) in the number of Horned Larks between treatment and control sites four days after application of zinc phosphide (Fig. 1). Relative densities of Horned Larks on the treatment sites were 50/10 ha, and control sites were 52/10 ha. No differences were found in relative densities between treated and control sites in June ($P = .479$) and July ($P = .486$) of 1984. The relative densities of Horned Larks in August 1984 were 93% higher (44/10 ha) on control sites than on treated sites (3/10 ha) ($P = .190$). In September 1984 similar trends were

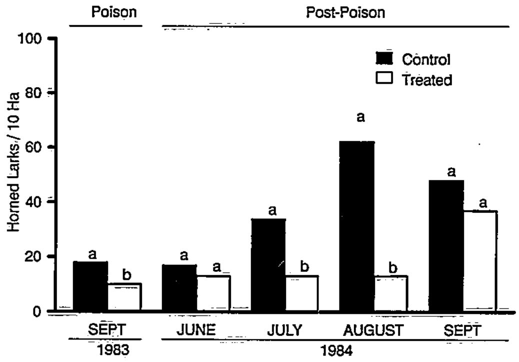

Fig. 3. Seasonal comparisons of Horned Lark densities on prebaited strychnine–treated and control sites from initial treatment in September 1983 through September 1984. Adjusted means are from covariance analysis. Statistical analysis was conducted on posttreatment minus pretreatment. Means followed by the same letter by date are not significant at $\alpha = 0.20$ after F-protection at $\alpha = 0.10$.

observed, but overall significant treatment effects were not evident ($P > .10$).

In 1983 Horned Lark densities were reduced 66% ($P = .109$; Fig. 2) on the strychnine only sites. No differences in relative densities for the Horned Lark occurred from June through September 1984 between treated and control sites ($P > .20$), indicating no long-term impacts.

Strychnine with prebait reduced Horned Lark relative densities 45% ($P = .128$; Fig. 3). By June 1984 Horned Lark densities were the

TABLE 1. Comparison of effects of zinc phosphide (ZnP) and strychnine (S-9) on Horned Lark relative densities/10 ha.

	Zinc phosphide versus strychnine			
	Adjusted effect			
Period	ZnP[a]	S-9[a]	Main effect[b]	Significance[c]
1983				
September	1 ± 19	−30 ± 19	31 ± 27	0.254
1984				
June	−5 ± 7	−4 ± 7	−1 ± 10	0.948
July	−6 ± 5	−2 ± 5	4 ± 7	0.717
August	−31 ± 3	3 ± 11	33 ± 11	0.183
September	−38 ± 20	−25 ± 20	−13 ± 28	NS[d]

[a]Effect adjusted through subtraction or analysis of covariance (mean ± standard error).
[b]Main effect calculated by difference of poisons.
[c]Probabilities calculated for contrasts in randomization test ($\alpha = 0.20$) based on variance heterogeneity after a significant F-protection at $\alpha = 0.10$ by analysis of variance or covariance.
[d]F-protection at $\alpha = 0.10$.

TABLE 2. Comparison of effects of zinc phosphide (ZnP) and prebaited strychnine (PS-9) on Horned Lark relative densities/10 ha.

	Zinc phosphide versus prebaited strychnine			
	Adjusted effect			
Period	ZnP[a]	PS-9[a]	Main effect[b]	Significance[c]
1983				
September	1 ± 19	−29 ± 19	30 ± 27	0.280
1984				
June	−5 ± 7	−2 ± 7	−2 ± 10	0.774
July	−6 ± 5	−20 ± 5	26 ± 7	0.020
August	−31 ± 3	−84 ± 11	53 ± 11	0.062
September	−38 ± 20	−32 ± 20	−6 ± 28	NS[d]

[a]Effect adjusted through subtraction or analysis of covariance (mean ± standard error).
[b]Main effect calculated by difference of poisons.
[c]Probabilities calculated for contrasts in randomization test ($\alpha = 0.20$) based on variance heterogeneity after a significant F-protection at $\alpha = 0.10$ by analysis of variance or covariance.
[d]F-protection at $\alpha = 0.10$.

same on treated and control sites ($P = .746$). In July 1984, 33 Horned Larks/10 ha were observed on the controls, while only 13/10 ha were on the treated sites ($P = .011$). In August relative densities of Horned Larks on control sites were 81% higher (62/10 ha) than on the treated sites (12/10 ha) ($P = .002$). By September 1984, however, there were no differences in relative densities between treated and control sites ($P > .10$).

Rodenticide Evaluation

The impact of zinc phosphide on Horned Larks was not different from that of strychnine only ($P = .254$; Table 1). In June and July 1984 there was no difference between the effects of zinc phosphide and strychnine on Horned Larks ($P = .948$ and $P = .717$, respectively). In August 1984 the effect of zinc phosphide was greater than that of strychnine ($P = .183$); however, in September 1984 no differences occurred between zinc phosphide and strychnine ($P < .10$).

A comparison of zinc phosphide and prebaited strychnine showed no differences in Horned Lark relative densities ($P = .280$) in September 1983 (Table 2). No differences were found between rodenticides in June 1984 ($P = .774$). During July and August 1984 differences were observed between zinc phosphide and prebaited strychnine ($P = .020$ and $P = .062$, respectively). Zinc phosphide showed less impact on Horned Lark densities than prebaited strychnine. However, in September 1984 no differences between zinc phosphide and strychnine were found ($P > .10$).

Strychnine only and prebaited strychnine were compared in September 1983, and no difference ($P = .964$) was found (Table 3). In June 1984 there was a difference of 2

TABLE 3. Comparison of effects of strychnine only (S-9) and prebaited strychnine (PS-9) on Horned Lark relative densities/10 ha.

Period	Strychnine versus prebaited strychnine			Significance[c]
	Adjusted effect			
	S-9[a]	PS-9[a]	Main effect[b]	
1983				
September	−30 ± 19	−29 ± 19	−1 ± 27	0.964
1984				
June	−4 ± 7	−2 ± 7	−2 ± 10	0.834
July	2 ± 5	−20 ± 5	22 ± 7	0.066
August	3 ± 11	−84 ± 11	87 ± 16	0.006
September	−25 ± 20	−32 ± 20	7 ± 28	NS[d]

[a]Effect adjusted through subtraction or analysis of covariance (mean ± standard error).
[b]Main effect calculated by difference of poisons.
[c]Probabilities calculated for contrasts in randomization test ($\alpha = 0.20$) based on variance heterogeneity after a significant F-protection at $\alpha = 0.10$ by analysis of variance or covariance.
[d]F-protection at $\alpha = 0.10$.

TABLE 4. Bird species observed and included in the granivorous guild in 1983 and 1984 on all 18 study sites in west central South Dakota.

American Crow (*Corvus brachyrhynchos*)
American Goldfinch (*Carduelis tristis*)
American Robin (*Turdus migratorius*)
Black-billed Magpie (*Pica pica*)
Chestnut-collared Longspur (*Calcarius ornatus*)
Common Grackle (*Quiscalus quiscula*)
European Starling (*Sturnus vulgaris*)
Grasshopper Sparrow (*Ammodramus savannarum*)
Lark Bunting (*Calamorpiza melanocorys*)
Lark Sparrow (*Chondestes grammacus*)
Mourning Dove (*Zenadia macroura*)
Red-winged Blackbird (*Agelaius phoeniceus*)
Ring-necked Pheasant (*Phasianus colchicus*)
Rock Dove (*Columba livia*)
Savannah Sparrow (*Passerculus sandwichensis*)
Sharp-tailed Grouse (*Tympanuchus phasianellus*)
Vesper Sparrow (*Poocecetes gramineus*)
Western Meadowlark (*Sturnella neglecta*)

Horned Larks/10 ha between the two treatments ($P = .834$). Differences for these two treatments were observed in July (22 Horned Larks/10 ha) and August (87 Horned Larks/10 ha) 1984 ($P = .066$ and $P = .006$, respectively). Sites with prebaited strychnine showed the greatest reduction in Horned Lark relative densities. In September 1984 no differences in impacts between strychnine and prebaited strychnine were found ($P > .10$).

Granivorous Avian Guild

Seed-eating birds were combined into a guild because of small sample sizes (Table 4). In September 1983 no treatment effect ($P > .10$) was found on the seed-eating guild with Horned Larks excluded. This was also true for June ($P = .754$), July ($P = .300$), and September ($P = .841$) 1984.

In August 1984 seed-eating bird densities on the zinc phosphide-treated sites were similar ($P = .454$) to the controls. On the strychnine-treated sites 4 birds/10 ha were found, and even though 5 birds/10 ha were observed on the control sites, the means were significantly different ($P = .181$). The prebaited strychnine treatment means were also higher, with 20 birds/10 ha on the treated sites and 3 birds/10 ha on the controls ($P = .030$).

Rodenticide Evaluation

In August 1984 the effective difference of the prebaited strychnine treatment was larger than for the zinc phosphide (−30 birds/10 ha) ($P = .173$) and strychnine (−22) ($P = .011$) treatments (Table 5). Zinc phosphide and strychnine impacts on the seed-eating guild were similar (−8) ($P = .721$).

DISCUSSION

Bait Availability

More poisoned grain remained on the prairie dog mounds following poisoning with strychnine than with zinc phosphide (Apa et al. 1990). This phenomenon is most likely related to the "taste factor" that accompanies strychnine and zinc phosphide. Prairie dogs more readily consume zinc phosphide. Also, the time factor involved before a toxic reaction occurs after poison consumption (Crabtree 1962) could influence bait quantities remaining. The toxic reaction time is faster for strychnine than zinc phosphide; therefore, more

TABLE 5. Comparison of effects of zinc phosphide (ZnP) and strychnine only (S-9), zinc phosphide and prebaited strychnine (PS-9), and strychnine only and prebaited strychnine on seed-eating bird relative densities/10 ha.

	August 1984					
	Zinc phosphide versus				Strychnine versus prebaited strychnine	
	ZnP	S-9	ZnP	PS-9	S-9	PS-9
Adjusted effect[a]	−18 ± 7	−10 ± 5	−18 ± 5	−12 ± 10	−10 ± 3	−12 ± 8
Main effect[b]	−8 ± 7		−30 ± 11		−22 ± 9	
Significance[c]	0.721		0.173		0.011	

[a]Effect adjusted through analysis of covariance (mean ± standard error).
[b]Main effect calculated by difference of poisons.
[c]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance heterogeneity after significant F-protection at α = 0.10 by analysis of covariance.

zinc phosphide could be consumed. These factors definitely affect availability of poisoned grain on prairie dog mounds following treatment.

Horned Larks

Treatments using zinc phosphide showed no direct impact on Horned Larks, but the two strychnine treatments did impact them. Strychnine is known for its avicidal efficacy (Courtsal 1983), but sparse documentation exists on its direct effects on birds. In this study, immediate direct losses were observed, and Horned Lark carcasses were found on the poisoned towns soon after poison application. Decreased relative densities of Horned Larks with both strychnine treatments were a result of direct poison toxicity and the large quantities of strychnine grain that remained on the mounds following posttreatment. The excess strychnine-treated grain was available to Horned Larks until bait disappeared or toxic effects were reduced. Hegdal and Gatz (1977a) found strychnine doses lethal to birds two months after poison application, resulting in significant reductions in Horned Lark populations in Wyoming.

There were no significant reductions in Horned Lark relative densities from zinc phosphide treatment because: (1) poison grain remaining was low, (2) birds have an aversion to black-colored foods (Rudd and Genelly 1956), and (3) birds have a negative sensory response to zinc phosphide (Siegfried 1968). Reduced impacts by zinc phosphide on birds have also been reported by Tietjen (1976), Tietjen and Matschke (1982), and Matschke et al. (1983). We believe zinc phosphide to be the preferred rodenticide for minimizing impacts on Horned Larks.

Indirect impacts on Horned Larks resulted from habitat changes. In 1984, when juveniles fledged, differences were observed between the control and treated sites. After the 1983 treatment of prairie dog colonies in the fall, Horned Larks nested on what appeared to be potential optimum habitat in spring 1984. Optimum nesting habitat consists of semibare or heavily grazed situations (Pickwell 1931, Dubois 1935, Bent 1968, Gietzentanner 1970, Creighton 1974). As summer progressed, prairie dogs were not available on treated sites to graze the spring growth. We observed many grasses (nonnative grasses and western wheatgrass) and forbs (prairie sunflower) that had obtained heights above the line of sight of ground-dwelling birds. Plant biomass increased and provided suitable habitat for Western Meadowlark, Lark Bunting, and Chestnut-collared Longspur (Giezentanner 1970).

In contrast, optimum habitat for Horned Larks was maintained by grazing of prairie dogs and other herbivores on the control sites throughout 1984. The low levels of prairie dog control achieved on the strychnine-treated towns (Apa et al. 1990) allowed surviving prairie dogs to consume vegetation and maintain optimum habitat for Horned Larks.

Granivorous Avian Guild

No immediate impacts on granivorous seed-eating birds were found, although we must acknowledge confounding individual effects that could influence results since we combined several granivorous species. Hegdal and Gatz (1977a) indicated that strychnine posed a threat to Red-winged, Yellow-headed (*Xanthocephalus xanthocephalus*), and Brewer's

(*Euphagus cyanocephalus*) Blackbirds; Vesper Sparrows; Western Meadowlarks; and Mourning Doves. Poisoned grains treated with zinc phosphide also posed a lesser threat to other seed-eating birds (Tietjen 1976, Hegdal and Gatz 1977b).

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LITERATURE CITED

AGNEW, W., D. W. URESK, AND R. M. HANSEN. 1986. Flora and fauna associated with prairie dog colonies and adjacent ungrazed mixed grass prairie in western South Dakota. Journal of Range Management 39: 135–139.

APA, A. D., D. W. URESK, AND R. L. LINDER. 1990. Black-tailed prairie dog populations one year after treatment with rodenticides. Great Basin Naturalist 50: 107–113.

BENT, A. C. 1968. Life histories of North American flycatchers, larks, swallows, and their allies. Dover Publications Inc., New York.

CARMER, S. G. 1976. Optimal significance levels for application of significant difference in crop performance trials. Crop Science 16: 95–99.

CARMER, S. G., AND M. R. SWANSON. 1973. An evaluation of ten pairwise multiple comparison procedures by Monte Carlo methods. Journal of American Statistics Association 68: 66–74.

COURTSAL, F. R. 1983. Pigeons (Rock Doves). Pages E35–E41 *in* R. M. Timm, ed., Prevention and control of wildlife damage. Great Plains Agriculture Council Wildlife Resources Committee, Nebraska Cooperative Extension Service, Lincoln.

CRABTREE, D. G. 1962. Review of current vertebrate pesticides. *In:* Vertebrate Pest Control Conference Proceedings, California Vertebrate Pest Control Tech, Sacramento. 390 pp.

CREIGHTON, P. D. 1974. Habitat exploration by an avian ground-foraging guild. Unpublished dissertation, Colorado State University, Fort Collins.

DUBOIS, A. D. 1935. Nests of Horned Larks and Longspurs on a Montana prairie. Condor 37: 56–72.

EDINGTON, E. S. 1980. Randomization tests. Marcel Dekker, Inc., New York. 287 pp.

EMLEN, J. T. 1971. Population densities of birds derived from transect counts. Auk 88: 323–342.

_____. 1977. Estimating breeding season bird densities from transect counts. Auk 94: 455–468.

GIEZENTANNER, J. B. 1970. Avian distribution and population fluctuations on the shortgrass prairie of north central Colorado. Unpublished thesis, Colorado State University, Fort Collins.

GREEN, R. H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley and Sons, New York. 257 pp.

HEGDAL, P. L., AND T. A. GATZ. 1977a. Hazards to seed-eating birds and other wildlife associated with surface strychnine baiting for Richardson's ground squirrels. EPA Final Report under Interagency Agreement EPA-IAG-D4-0449.

_____. 1977b. Hazards to pheasants and cottontail rabbits associated with zinc phosphide baiting for microtine rodents in orchards. EPA Final Report under Interagency Agreement EPA-IAG-D4-0449.

MATSCHKE, G. H., M. P. MARSH, AND D. L. OTIS. 1983. Efficacy of zinc phosphide broadcast baiting for controlling Richardson's ground squirrels on rangelands. Journal of Range Management 36: 504–506.

MERRIAM, C. H. 1902. The prairie dog of the Great Plains. Pages 257–270 *in* Yearbook of the United States Department of Agriculture. Government Printing Office, Washington, D.C

NICKERSON, M. F., G. E. BRINK, AND C. FEDEMA. 1976. Principal range plants of the central and southern Rocky Mountains: names and symbols. United States Department of Agriculture, Forest Service. General Technical Report RM-20, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 121 pp.

PICKWELL, G. A. 1931. The Prairie Horned Lark. Transactions of the Missouri Academy of Science (St. Louis) 27: 1–153.

RAYMOND, W. H., AND R. U. KING. 1976. Geological map of the Badlands National Monument and vicinity, west-central South Dakota. United States Geological Survey. Map I-934.

ROMESBURG, C. 1981. Randomization test. Resource Evaluation Newsletter. Pages 1–3. Technical Article 1. USDI-BLM, Denver Colorado.

ROOT, R. B. 1967. The niche exploitation pattern of the Blue-grey Gnatcatcher. Ecological Monographs 37: 317–349.

ROTENBERRY, J. T. 1982. Birds in shrubsteppe habitat. Pages 307–309 *in* D. E. Davis, ed., Handbook of census methods for terrestrial vertebrates. CRC Press, Inc., Boca Raton, Florida.

RUDD, R. L., AND R. E. GENELLY. 1956. Pesticides: their use and toxicity in relation to wildlife. California Fish and Game Bulletin No. 7.

SCHENBECK, G. L. 1982. Management of black-tailed prairie dogs on the National Grasslands. Pages 207–217 *in* R. M. Timm and R. J. Johnson, eds., Fifth Great Plains Wildlife Damage Control Workshop Proceedings, 13–15 October 1981, University of Nebraska, Lincoln.

SIEGFRIED, W. R. 1968. The reaction of certain birds to rodent baits treated with zinc phosphide. Ostrich 39: 197–198.

TIETJEN, H. P. 1976. Zinc phosphide—its development as a control agent for black-tailed prairie dogs. United States Department of Interior, Fish and Wildlife Service Special Science Report Wildlife No. 195. 14 pp.

TIETJEN, H. P., AND G. H. MATSCHKE. 1982. Aerial prebaiting for management of prairie dogs with zinc phosphide. Journal of Wildlife Management 46: 1108–1112.

URESK, D. W., R. M. KING, A. D. APA, AND R. L. LINDER. 1986. Efficacy of zinc phosphide and strychnine for black-tailed prairie dog control. Journal of Range Management 39: 298–299.

URESK, D. W., R. M. KING, A. D. APA, M. S. DEISCH, AND R. L. LINDER. 1988. Rodenticidal effects of zinc phosphide and strychnine on nontarget species. Pages 57–63 *in* D. W. Uresk, G. L. Schenbeck, and R. Cefkin, tech. coordinators, Eighth Great Plains Wildlife Damage Control Workshop Proceedings, Fort Collins, Colorado, GTR RM-154. USDA Forest Service Rocky Mountain Forest and Range Experiment Station.

USDI. 1956. Prairie dogs and their control. United States Department of the Interior, Fish and Wildlife Leaflet No. 357. 4 pp.

VAN BRUGGEN, T. 1976. The vascular plants of South Dakota. Iowa State University Press, Ames.

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