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Efficiency of Two Black-tailed Prairie Dog Rodenticides and Their Impacts on Non-target Bird Species

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EFFICIENCY OF TWO BLACK-TAILED PRAIRIE DOG RODENTICIDES AND THEIR IMPACTS ON NON-TARGET BIRD SPECIES

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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EFFICIENCY OF TWO BLACK-TAILED PRAIRIE DOG RODENTICIDES
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Abstract

ANTHONY DEAN APA

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 (4 days later) and long-term (1 year later) poison efficiency and impact (short-term and long-term) on horned larks (Eromophila alpestrus) and other seed-eating birds of the prairie dog colonies were evaluated. Prairie dog burrow densities ranged from 54-187 burrows/ha with an average burrow density of 114 ± 8 (± SE) burrows/ha. Rodenticide short-term control reduced active burrows by 95% with zinc phosphide, 42% with only strychnine, and 78% with prebaited strychnine. More zinc phosphide was consumed after poisoning than strychnine. Long-term control was maintained with prebaited strychnine and zinc phosphide but not with strychnine only. Fifty species of birds were observed. Immediate impacts with poisons reduced horned lark relative densities 66% with strychnine only and 45% with prebaited strychnine. No measurable reduction was found with zinc phosphide. No direct long-term impacts on horned larks were found. Indirect impacts occurred on horned larks through habitat changes from prairie dog control. No short-term or long-term poison impacts were found on the seed-eating avian group.

INTRODUCTION

The black-tailed prairie dog (Cynomys ludovicianus) is a native inhabitant of the North American Great Plains. Original range of the prairie dog extended from Saskatchewan to Mexico and was characteristic of the short and midgrass prairies (Hall 1981). Habitat was restricted on the east by the tall grass prairie and the west by the Rocky Mountains (Koford 1958, Bonham and Lerwick 1976). In the United States the black-tailed prairie dog inhabited over 4 million hectares in 1919 (Nelson 1919), and Seton (1928) estimated the population at 5 billion individuals. However, by 1960 poisoning campaigns initiated in the late nineteenth century (Bell 1920) had reduced prairie dog populated rangeland to 600,000 hectares (U.S. Dept. of Interior 1963).

Originally prairie dog control was justified on the basis that prairie dogs compete with livestock (cattle) for forage and alter plant community composition to less desirable situations for grazing (Merriam 1902, Keslo 1939, Stoddart and Smith 1975, Vallentine 1971, Hansen and Gold 1977, Uresk et al. 1981). Hansen and Gold (1977) found that prairie dogs have a diet similarity index of 64% with cattle. Bonham and Lerwick (1976) stated that prairie dogs were selective herbivores and that they scarify the soil which increased plant diversity. In the selection process, they altered the plant community composition from a buffalo grass (Buchloe dactyloides) and blue grama (Bouteloua gracilis) complex to a community higher in forb production (Uresk and Bjugstad 1983). These changes in plant composition and/or vegetation biomass convinced managers and landowners that control of prairie dogs was justified.

Concern for agricultural losses in South Dakota from prairie dog depredations began during the late nineteenth century (Merriam 1902). A survey by the U.S. Department of Agriculture (1981) in 1980 showed that the economical loss to pastures, ranges, and crops, caused by prairie dogs, was $9.57 million. Even with extensive economical losses, Collins et al. (1984) reported that prairie dog control by private and Federal land managers was not economically feasible. It was more cost effective for a private rancher to poison prairie dogs than for Federal managers.

Prairie dog populations fluctuated naturally prior to the turn of the century. In the past 80 years fluctuations have been largely man-induced. In 1923 there were 702,688 hectares of prairie dogs in South Dakota, but by 1967 poisoning efforts had reduced the area occupied by prairie dogs to 14,688 hectares (Henderson et al. 1974). Prairie dog populations began to increase in the 1970's. Rose (1973) estimated that 24,000 hectares of grassland in South Dakota were inhabited by prairie dogs, and in 1972 the Buffalo Gap and Fort Pierre National Grasslands alone had 8,405 hectares of prairie dogs (Schenbeck 1982). Presently, it is estimated that 292,000 hectares of prairie dogs exist in South Dakota (R. V. Hanson, pers. commun. USFWS, Pierre, SD).

Poisons applied to oats have been and are the primary tool for prairie dog 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 United States Department of Agriculture at the beginning of the century (Merriam 1902, Crabtree 1962). Two characteristics that may have impeded its acceptance by rodents were its bitter taste and noxious effect when sub-lethal doses were consumed. Crabtree (1962) noted that rodents quickly learned to associate the taste of strychnine with its toxic effect and avoid additional exposures. Attempts to circumvent taste and toxic effects by rodents have failed (Crabtree 1962). Besides the inconsistent treatment effects in certain situations, strychnine was considered hazardous to many nontarget species (Tietjen 1976a).

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 monofluoroacetate (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 1976a). Since 1976, zinc phosphide has been the only rodenticide available for Federally involved prairie dog control. Bioassays have shown that zinc phosphide causes no secondary poisoning effects to predatory or scavenging species (Crabtree 1962, Tietjen 1976a). Zinc phosphide was also shown to be an effective toxicant for prairie dog control (Crabtree 1962, Tietjen 1976a, Tietjen and Matschke 1982).

Several seed-eating avain species inhabit black-tailed prairie dog colonies (Agnew et al. In Press). Birds residing on prairie dog colonies that may be primarily affected by the poison are those of seed-eating guilds (Root 1967, Creighton 1974) which consume grains treated with poisons. However, quantitative estimates that evaluate poison impacts on avian residents have not been documented. Tietjen (1976a) observed horned larks (Eromophila alpetris) and mourning doves (Zenaida macroura) on zinc phosphide treated prairie dog colonies, but observations after treatment failed to show sick or dead birds. In contrast, Hegdal and Gatz (1977a) found significant kills of nontarget seed-eating birds, especially horned larks and mourning doves, when strychnine treated grain was applied to Richardson's ground squirrel (Citellus richardsonii) colonies. The U.S. Dept. of Interior (1956) acknowledged that nontarget losses occurred following exposure to strychnine and advised that one should make attempts to minimize the effects.

The objectives of this study were to determine effects of zinc phosphide, strychnine with prebait, and strychnine without prebait on prairie dog colonies, specifically.

1) Short- and long-term impacts on nontarget birds and

2) Efficiency of these rodenticide treatments for control of black-tailed prairie dogs.

In this study long-term impacts were evaluated 1 year following rodenticide application.

STUDY AREA

The study area was located on Badlands National Park and Buffalo Gap National Grassland in west central South Dakota (Fig. 1). The 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 total precipitation falls as thundershowers during April to September, and rainfall can be localized or cover large areas. Temperatures range from a -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 study 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.

A mosaic of native grasses, forbs, shrubs, and isolated trees comprise the vegetation. Dominant grasses include bluegrama, buffalograss, 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 was pasture sage-brush (Artemisia frigida). Non-native grasses included cheat grass (Bromus tectorum), and Japanese chess (B. japonicus). Scientific names of plants follow Nickerson et al. (1976) and

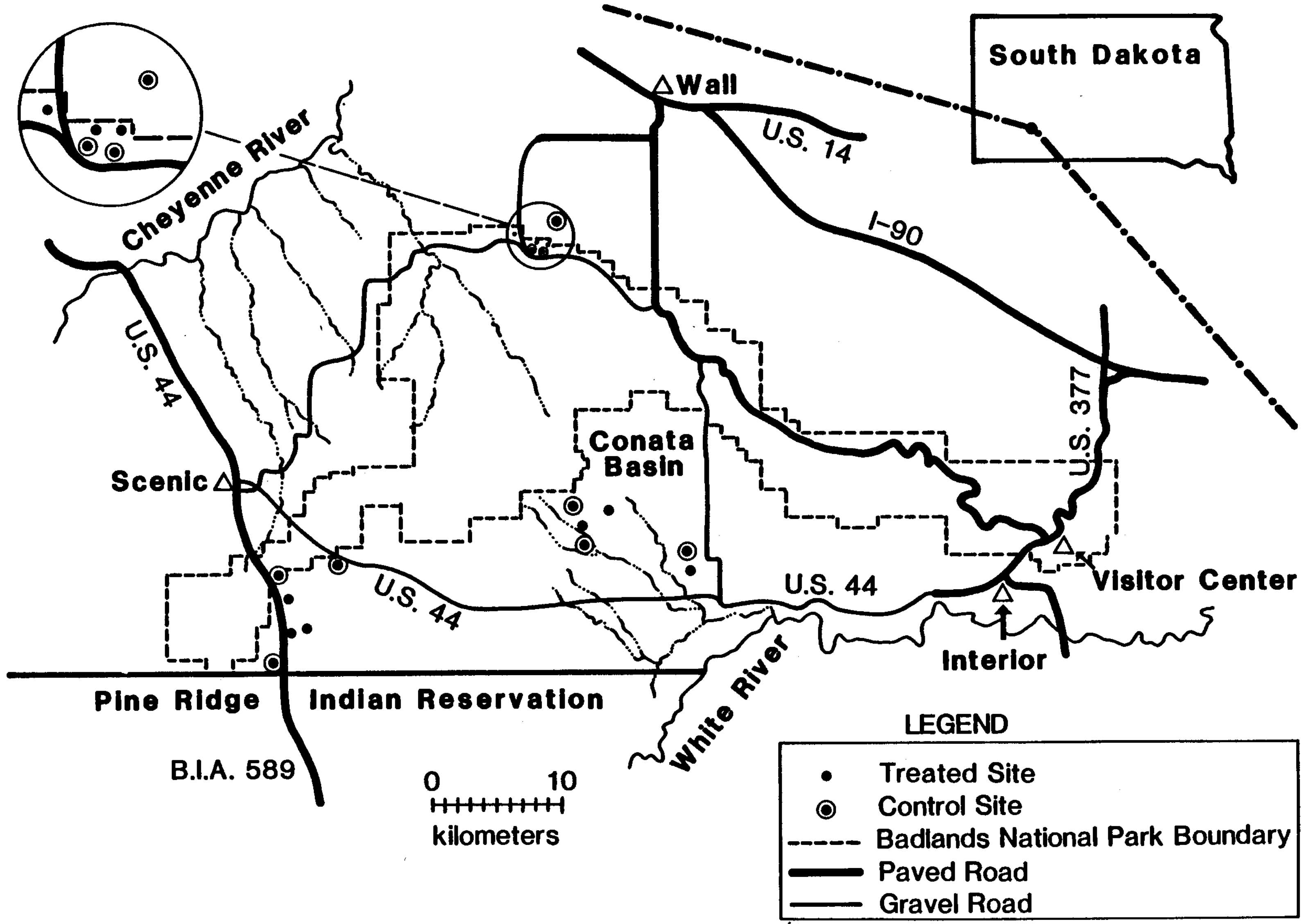

Fig. 1. Map showing locations of the 9 treated and 9 control sites near Wall, South Dakota

Van Bruggen (1976). Native herbivores that inhabited the Badlands region were black-tailed prairie dog, mule deer (Odocoileus hemionus), Rocky Mountain big horn sheep (Ovis canadensis), American bison (Bison bison), pronghorn (Antilocapra americana), blacktailed jackrabbit (Lepus californicus), whitetailed jackrabbit (L. townsendii), and eastern cottontail (Sylvilagus floridanus). Small rodents included deer mouse (Peromyscus maniculatus) and grasshopper mouse (Onychomys leucogaster). Livestock were not present in the Park but bison grazed all year. Cattle were allowed to graze the National Grassland 6 months during the growing season each year.

METHODS

Eighteen sites on 15 prairie dog colonies were sampled in 1983 and 1984 with 9 sites designated as treatments and 9 as controls (Fig. 1). Sites were clustered into 3 major areas and each rodenticide treatment had 3 treated and 3 control sites. Zinc phosphide was applied to the area within Badlands National Park because administrative restraints did not allow the use of strychnine. Four sites were clustered and paired on an approximately 600 ha prairie dog colony. The other 2 sites were located on prairie dog colonies northwest of the larger colony, and northeast on a colony in the Buffalo Gap National Grassland. Strychnine with and without prebait treatments were randomly assigned to the 2 remaining areas on the National Grasslands. The area with prebaited strychnine was located in Conata Basin while the area treated with strychnine only was located east and south of Scenic. All 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 U.S. Forest Service imposed administrative restrictions.

PRAIRIE DOG BURROWS

The open burrow technique was used to determine the effectiveness of the zinc phosphide and strychnine by evaluating the number of active burrows (Tietjen and Matschke 1982). Burrow entrances in a 100 X 100 m area (1 ha) were filled (plugged) with soil preventing egress/ingress by prairie dogs. Forty-eight hours later the number of reopened burrows, large enough for prairie dogs to pass through, was counted. Burrow activity for pretreatment periods was collected in June, July, and early-September in 1983. Posttreatment measurements occurred in late-September 1983 (4 days following poisoning), and the following year in June, July, August, and early-September 1984.

BIRDS

Avian populations were sampled on 18 permanent 805 m by 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), Emlen (1977), and Rotenberry (1982). The observer walked the transect line and counted birds up to 31 m from either side of the line. Sampling began one-half hour after sunrise and continued approximately 4-5 hours; average walking time was 15-25 minutes per transect. Sampling was conducted 4 consecutive days each session. Birds hovering over and/or flying through the transect were tallied. Four pretreatment sampling sessions included June, July, August, and early-September prior to poisoning prairie dogs in 1983. The sampling session in early-September occurred 1 week prior to poisoning. The first posttreatment session in late-September commenced 4 days after treatment. Four posttreatment sampling sessions were conducted in 1984 corresponding with the 1983 pretreatment sampling sessions. Identification authority for birds was Peterson (1961) and American Ornithologist's Union (1982).

BAIT FORMULATION AND APPLICATION

Treated and untreated steam-rolled oats were formulated and obtained from the United States Fish and Wildlife Service (USFWS), Pocatello Idaho Supply Depot. Each poison bait was marked with a specific tracerite marker. Tracerites floresced when exposed to black (UV) light, and poisons were not discolored by the tracerites.

Poisons were applied in the field when proper environmental conditions existed insuring optimum consumption of oats by prairie dogs (Tietjen 1976a, Tietjen 1976b, Tietjen and Matschke 1982). Poison application was in accordance with Federal label instructions. The untreated oats (prebait) and the poisoned oats were applied from Honda 3-wheel drive ATC's fitted with bait dispensers (Schenbeck 1982). Smaller acreages were treated by hand using teaspoons (H. P. Tietjen pers. commun. USFWS, Denver, CO.).

Four grams of high-quality untreated steam-rolled oats were applied as prebait for prairie dogs at each burrow. Three sites were prebaited on 20 September 1983 and 3 on 21 September 1983. A minimum of 95% of the burrows was prebaited. Prebait was applied ($\leq$ 01m^2 area) at edges of prairie dog mounds.

Prebaited areas were examined prior to application of poisons to assure that the prebait was consumed by prairie dogs. Three days after prebait application (22 September 1983), 3 sites were treated with 4 g of 2.0% active zinc phosphide steam-rolled oats.[1] Three additional sites were treated with 8 g of 0.5% strychnine alkaloid steam-rolled oats per burrow on 23 September 1983. The last 3 sites were treated with strychnine oats on 24 September 1983, but not prebaited. Three days after poisoning the percent of poisoned oats remaining on each burrow in a 1 hectare grid on each treated site was estimated.

STATISTICAL ANALYSES

Evaluation of impacts for each poison was compared using changes from pretreatment and posttreatment data on each treatment regime (area) with changes observed on their respective control sites. The change from year 1983 (pretreatment) to 1984 (posttreatment), and immediately before (pretreatment) and after (posttreatment) poison application was evaluated (SAS 1981, SAS 1982a, SAS 1982b).

When a significant ($\alpha < 0.20$) correlation was found between pretreatment and posttreatment values, analysis of covariance was used to estimate the change in the posttreatment observations when adjusted for the pretreatment observations, the covariate. The adjustment was

$$Z_{ij} = Y_{ij} - b..(X..-\bar{X}..), \quad (1)$$

---

[1]Alcolec S is used as an adhesive made by the American Lecithin Co., Inc.

where Z_{ij} is the adjusted observation for the j-th site in the i-th treatment regime, Y_{ij} is the posttreatment observation, b.. is the overall regression coefficeint (N = 18), X_{ij} is the pretreatment observation and $\bar{X}..$ is the overall pretreatment mean. When the interaction between the covariate and the treatment was significant ($\alpha \leqq 0.10$) individual areas were adjusted (N = 3) using Equation 1.

If the correlation between pretreatment and posttreatment observations was not significant ($\alpha \leqq 0.20$) or if the covariate was acting independant from the treatment (tested using analysis of variance $\alpha = 0.10$) (Steel and Torrie 1980), then the change between pretreatment and posttreatment was adjusted as follows

$$Z_{ij} = Y_{ij} - X_{ij}. \qquad (2)$$

This analysis was based on an interaction between time and treatment as the indicator of a significant change due to treatment (Green 1979).

After the form of the variable (Z_{ij}) was determined, specific contrasts between respective treatment and control groups were calculated as $C_1 = \bar{Z}_1 - \bar{Z}_2$, $C_2 = \bar{Z}_3 - \bar{Z}_4$, $C_3 = \bar{Z}_5 - \bar{Z}_6$. Here, $\bar{Z}$, was the estimated average change on the treated zinc phosphide sites and $\bar{Z}_2$ is the estimated average change on the respective control.

When differences among treatments were indicated by covariance adjustment or by the interaction between time and treatment (F - protection for Type I error was $\alpha \leqq 0.10$) comparisons among poisons were produced by forming contrasts $C_4 = C_1 - C_2$, $C_5 = C_3 - C_4$, $C_6 = C_5 - C_6$. A randomization procedure was used to estimate statistical significance of various contrasts (Mosteller and Rourke 1973, Edington 1980, Romesburg 1981). The randomization test does not rely on the normality assumption inherent in typical parametric tests such as analysis of variance (Edington 1980, Romesburg 1981). The test provides exact probabilities for individual contrasts. A test statistic (t) was calculated within the randomization procedure for each contrast (C_i)

$$t=C_i/Sqrt(Var\ C_i), \quad (3)$$

and significant levels were estimated on 10,000 random permutations of adjusted data pairs (X_{ij}, Y_{ij}) among the treatment clusters. The variance of the contrast (Var C_i) was determined from the sum of the variances of the means in the contrast. Individual variances computed were based on the covariance and homogeneity assumptions for the particular variable.

The occurrence of a Type I error was not considered as serious as a Type II error within the analyses. The rejection of a poison impact was considered more serious than the incorrect acceptance of a significant poison effect, therefore Type II error protection was produced by testing each individual contrast, only after a significant ($\alpha = 0.10$) overall test of treatment differences using analysis of variance or covariance. Some Type I error was provided by observing a significant ($\alpha \leqq 0.10$) difference due to treatment through analysis of variance or covariance (Carmer and Swanson 1973).

Individual contrasts, after significant treatment differences were considered to be biologically different at $\alpha \leqq 0.20$. Considering the number of sites available for this study an alpha of 0.20 produced a power (probability of detecting a true difference) of 0.80. Biological inferences made from this study were considered reasonable because of the satisfactory combination of Type I, Type II, Type III error protection (Carmer 1976).

RESULTS

PRAIRIE DOG BURROWS

Prairie dog burrow density and activity varied over all treatment areas. The zinc phosphide area averaged 102 $\pm$ 9 ($\pm$ SE) burrows/ha, ranging from 64-129 burrows/ha. The strychnine treated area had 113 $\pm$ 14 burrows/ha, and ranged from 66-150 burrows/ha. The strychnine with prebait area, averaged 128 $\pm$ 20 burrows/ha, with a range from 54-187 burrows/ha. Over all 18 sites in 1983 and 1984 the mean burrow density was 114 $\pm$ 8 burrows/ha, and ranged from 54-187 burrows.

Prairie dog burrow activity showed monthly trends both years (Table 1). In 1983, the number of active burrows was high in June (81%) and steadily decreased until late-September when 35% of the burrows were active. In 1984 spring activity of prairie dog burrows was high (78%) and decreased through July and August, but increased to 75% in September.

In September 1983, the initial reduction of active prairie dog burrows with zinc phosphide was different from the control ($P = 0.014$, Fig. 2). Active burrows were reduced by 95%. This reduction in the number of active burrows was maintained (96%) in June of 1984 ($P = 0.002$). The trend continued in July (92%) and September (77%) of 1984, and number of active burrows remained different from the controls ($P = 0.006$, and $P = 0.014$, respectively). Additional information on pretreatment and posttreatment values is presented in Appendix Tables 1, 2, 3, and 4.

Table 1. Average number of black-tailed prairie dog burrow/ha, active/ha, and percent active/ha (± standard error of the mean) for four sampling periods in 1983 and on untreated areas in 1984 in west-central South Dakota.

	1983				1984[1]			
Parameters	June[2]	July[2]	early-Sept[2]	late-Sept[1]	June	July	August	early-Sept
Total burrows	121±9	117±9	113±8	104±13	104±13	103±14	97±15	86±15
Number active	98±8	87±8	48±5	34±4	82±12	66±10	54±11	66±13
Percent active	81±3	74±3	43±3	35±4	77±4	64±3	55±4	75±3

[1]N=9 sites.

[2]N=18 sites.

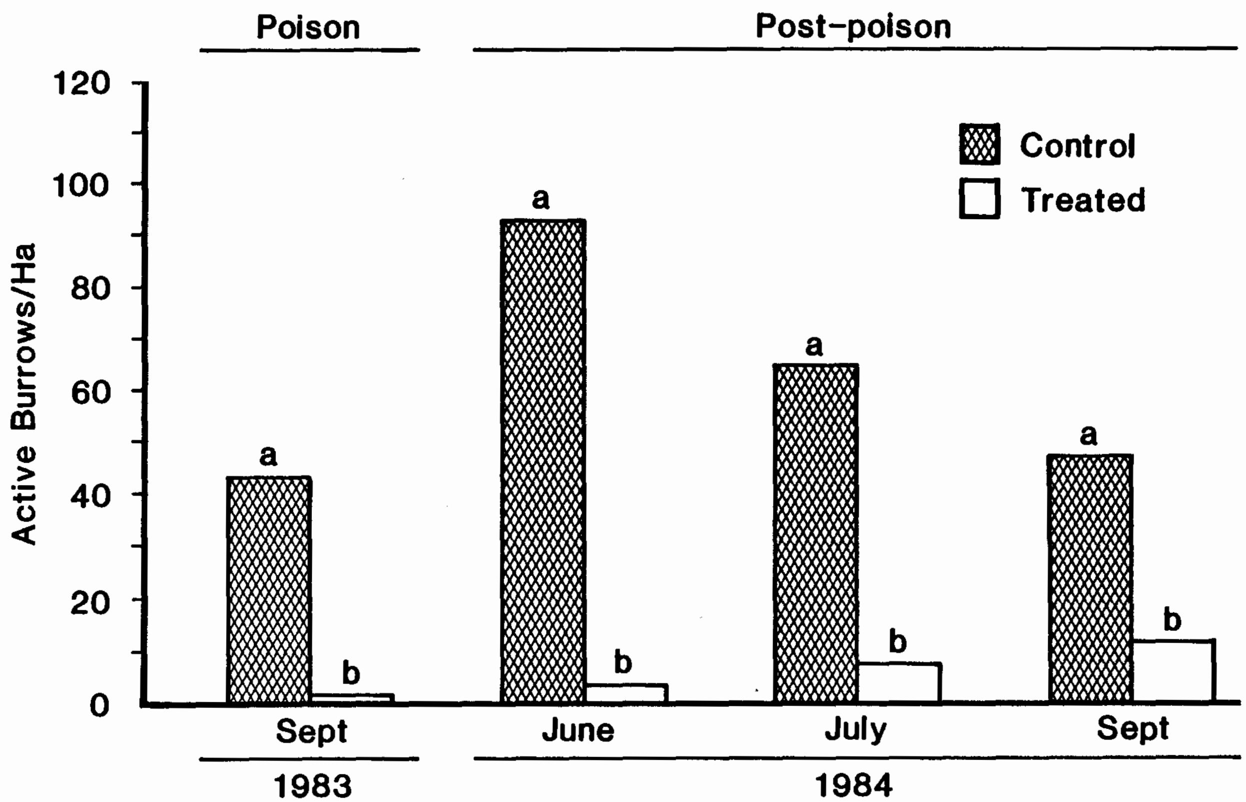

Fig. 2. Seasonal comparisons of active black-tailed prairie dog burrows on zinc phosphide treated and control sites from initial treatment in September 1983 through September 1984. Means followed by the same letter by date are not significant at $\alpha = 0.20$, after F-protection at $\alpha = 0.10$ using analysis of covariance.

During initial treatment when strychnine alone was applied for prairie dog control, there was a 42% reduction in active burrows (P = 0.167, Fig. 3). In June 1984, active burrows on the treated sites remained 45% below the strychnine control sites (P = 0.177). The trend changed in July when number of active burrows on the treated sites was not different from the controls (P = 0.706). The treated and control sites also showed similar burrow activity levels in September (P = 0.637). Appendix Tables 1, 2, 3, and 4 provide additional information on pretreatment and posttreatment burrow activity with adjusted main effects.

Seasonal trends of black-tailed prairie dog colonies prebaited and then treated with strychnine are presented in Fig. 4. In September 1983, initial reduction in number of active burrows from the control site was 78% (P = 0.038). In June 1984, reduction was 85% below (P = 0.019) the controls, and this level continued in July (99%), and September (95%) 1984. The lower number of active burrows for July and September was different (P = 0.083 and P = 0.057, respectively) from controls. Appendix Tables 1, 2, 3, and 4 provide additional data on burrow activity.

A comparison of the effectiveness of rodenticides at initial poisoning of prairie dogs in 1984 showed that number of active burrows reduced with zinc phosphide was greater than strychnine alone (P = 0.034) (Table 2). Again in June 1984, burrow counts showed that

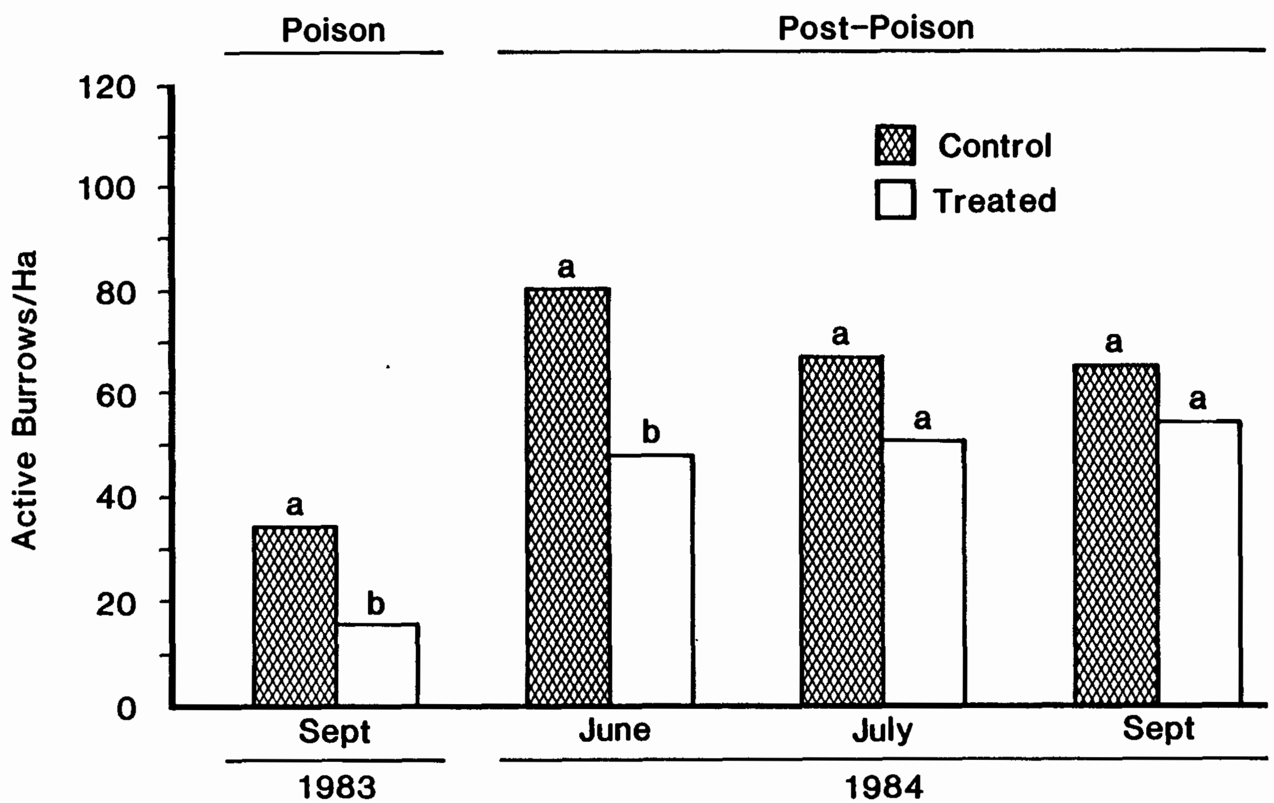

Fig. 3. Seasonal comparisons of active black-tailed prairie dog burrows on strychnine only treated and control sites from initial treatment in September 1983 through September 1984. Means followed by the same letter by date are not significant at $\alpha = 0.20$ after F-protection at $\alpha = 0.10$ using analysis of covariance.

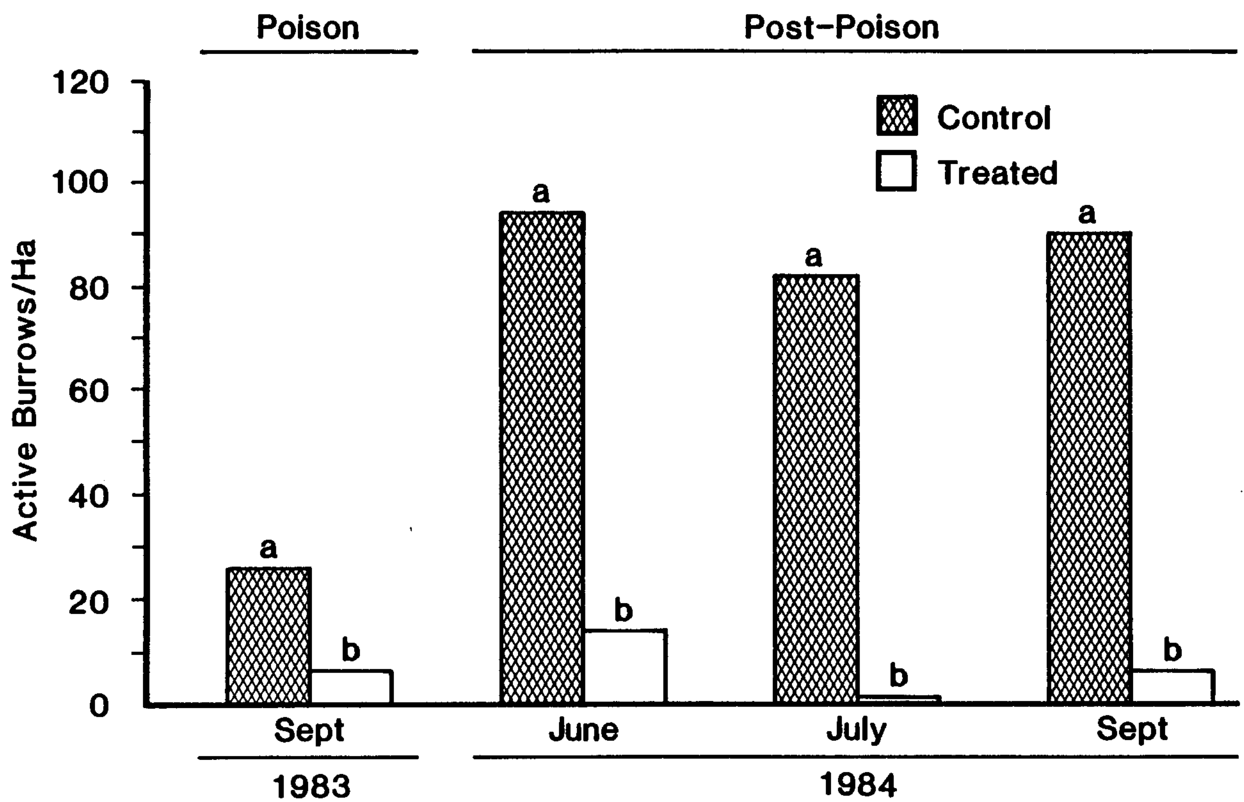

Fig. 4. Seasonal comparisons of active black-tailed prairie dog burrows on prebaited strychnine treated and control sites from initial treatment in September 1983 through September 1984. Means followed by the same letter by date are not significant at $\alpha = 0.20$ after F-protection at $\alpha = 0.10$ using analysis of covariance.

Table 2. Effectiveness of black-tailed prairie dog control with zinc phosphide (ZnP) compared with unprebaited strychnine (S-9) through time (mean active burrows/ha ± standard error).

	Zinc Phosphide		Versus Strychnine	
	Adjusted Effect			
Period	ZnP[1]	S-9[1]	Main Effect[2]	Significance[3]
1983				
Sept	-45±12	-14±9	-31±15	0.034
1984				
June	-86±2	-22±12	-64±9	0.006
July	-59±1	10±6	-69±7	0.035
Sept	-42±4	- 7±8	-38±10	0.039

[1]Effect adjusted using analysis of covariance.

[2]Main effect calculated by difference of poisons.

[3]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance heterogeneity after a significant F-protection at α = 0.10 by analysis of covariance.

zinc phosphide treated towns had fewer (P = 0.006) active burrows than strychnine. This trend continued through July (P = 0.035) and September (P = 0.039) 1984.

A comparison of zinc phosphide to prebaited strychnine showed a difference in active burrows (P = 0.080) during September 1983 (Table 3). Zinc phosphide showed the greatest reduction in burrow activity. After initial treatment there were no differences between rodenticides in 1984 (P > 0.20).

Reduction in active burrows when both strychnine treatments were compared was not different (P = 0.380) in September 1983 (Table 4). The effectiveness of strychnine and prebaited strychnine for control was compared in June 1984, with an average effective difference of 60 active burrows (P = 0.029). The same trend continued throughout 1984 in July (P = 0.078) and September (P = 0.062).

BAIT CONSUMPTION

More zinc phosphide was consumed by prairie dogs 4 days after treatment than strychnine (P = 0.036) or prebaited strychnine (P = 0.012. Fig. 5). Burrows treated with zinc phosphide had 72 ± 7% (± SE) of the poisoned oats consumed. The strychnine treatments had 16 ± 2% and 8 ± 1% of the bait consumed, respectively. There was no difference (P = 0.762) in the amount of poison bait consumed by prairie dogs between strychnine treatments.

Table 3. Effectiveness of black-tailed prairie dog control with zinc phosphide (ZnP) compared with prebaited strychnine (PS-9) through time (mean active burrows/ha ± standard error).

	Zinc Phosphide		Versus Prebaited Strychnine	
	Adjusted Effect			
Period	ZnP[1]	PS-9[1]	Main Effect[2]	Significance[3]
1983				
Sept	-45±12	-23±4	-22±16	0.080
1984				
June	-86±2	-82±13	- 4±9	0.872
July	-59±1	-67±32	9±33	0.775
Sept	-42±4	-77±28	-33±31	0.358

[1]Effect adjusted using analysis of covariance.

[2]Main effect calculated by difference of poisons.

[3]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance heterogeneity after a significant F-protection at α=0.10 by analysis of covariance.

Table 4. Effectiveness of black-tailed prairie dog control with strychnine (S-9) compared with prebaited strychnine (PS-9) through time (mean active burrow/ha ± standard error).

	Strychnine	Versus Prebaited Strychnine		
	Adjusted Effect			
Period	S-9[1]	PS-9[1]	Main Effect[2]	Significance[3]
1983				
Sept	-14±9	-23±4	9±11	0.380
1984				
June	-22±12	-82±13	60±5	0.029
July	10±6	-68±32	78±26	0.078
Sept	- 7±8	-77±28	69±26	0.062

[1]Effect adjusted using analysis of covariance.

[2]Main effect calculated by difference of poisons.

[3]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 covariance.

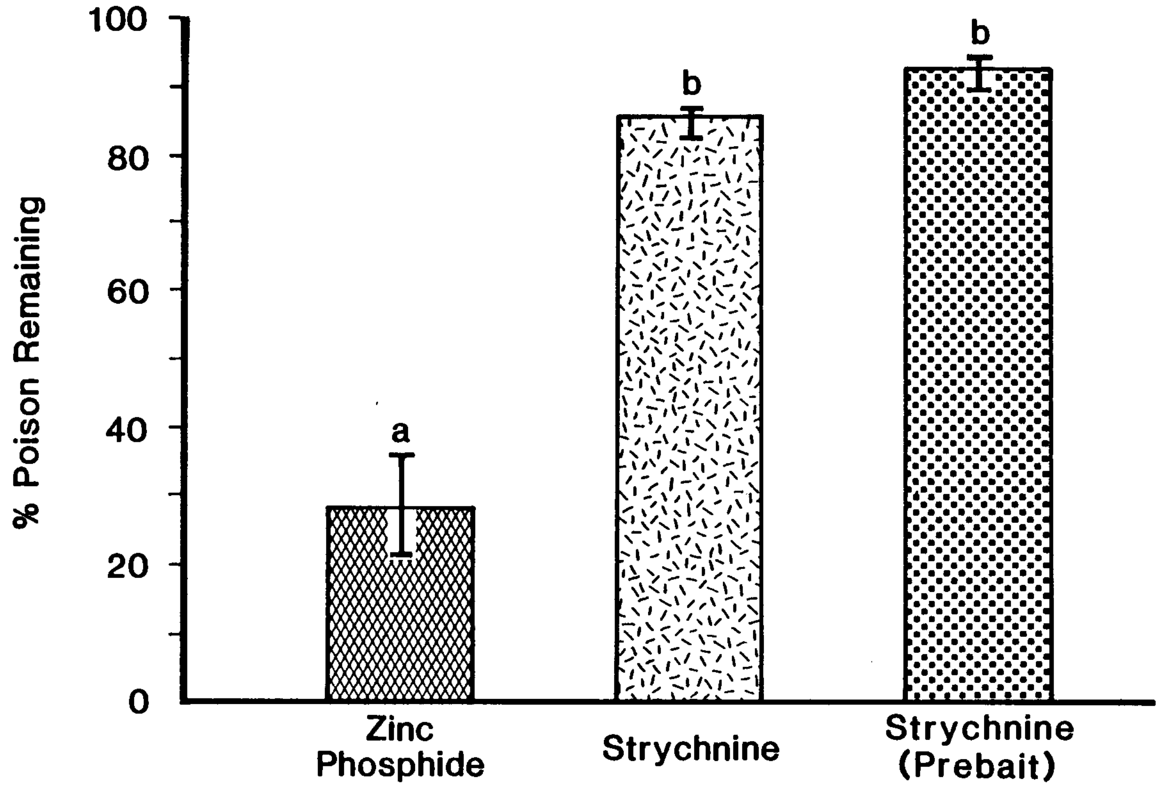

Fig. 5. Average percent (+ standard error of mean) of zinc phosphide, strychnine only, and prebaited strychnine (treated steam-rolled oat) remaining 4 days after treatment to black-tailed prairie dogs. Means followed by the same letter for each poison are not significant at $\alpha = 0.05$ after F-protection at $\alpha = 0.05$.

BIRDS

Forty-six and 40 species of birds were observed on all sites in 1983 and 1984, respectively (Table 5). Eighteen bird species present on the sites were different between years. Total bird observations in 1983 were 8,639 with 65% horned larks and 14% western meadowlarks. However, in 1984 total bird observations were 5,965 with horned larks accounting for 56% and western meadowlarks 18%. Individual bird species did not exceed 5% either year, and unidentified species were less than 1%.

HORNED LARKS

There were no differences (P = 0.977) in the number of horned larks between treatment and control sites 4 days after application of zinc phosphide (Fig. 6). Relative densities of horned larks on the treatment sites were 50/10 ha and control sites were 52/10 ha. Differences were not found in relative densities between treated and control sites (P = 0.479 and P = 0.486, respectively) in June and July 1984. The relative densities of horned larks in August 1984 were 93% higher (44/10 ha) on control sites than on the treated sites (3/10 ha) (P = 0.190). In September similar trends were observed, but significant treatment effects were not evident (P > 0.10). Pretreatment and posttreatment relative densities of horned larks with statistical analysis are presented in Appendix Tables 5, 6, 7, 8, and 9.

Table 5. Bird species observed in 1983 and 1984 on all 18 study sites in west-central South Dakota.

American crow (*Corvus brachyrhynchos*)[1]

American goldfinch (*Carduelis tristis*)[1]

American kestrel (*Falco sparverius*)

American robin (*Turdus migratorius*)[1]

Barn swallow (*Hirundo rustica*)

Black-billed magpie (*Pica pica*)[1]

Blue-winged teal (*Anas dicors*)

Burrowing owl (*Arhene cunicularia*)

Canada goose (*Branta canadensis*)

Canvasback (*Aythya valisineria*)

Chestnut-collared longspur (*Calcarius ornatus*)[1]

Cliff swallow (*Hirundo pyrrhonota*)

Common grackle (*Quiscalus quiscula*)[1]

Common nighthawk (*Chordeiles minor*)

Eastern kingbird (*Tyrannus tyrannus*)

European starling (*Sturnus vulgaris*)[1]

Ferruginous hawk (*Buteo regalis*)

Gadwall (*Anas strepera*)

Golden eagle (*Aquila chrysatetos*)

Grasshopper sparrow (*Ammodramus savannarum*)[1]

Great blue heron (*Ardea herodias*)

Horned lark (*Eromophila alpestris*)[2]

Killdeer (*Charadrius vociferus*)

Table 5. Continued

Lark bunting (*Calamorpiza melanocorys*)[1]
Lark sparrow (*Chondestes grammacus*)[1]
Loggerhead shrike (*Lanius ludovicianus*)
Long-billed curlew (*Numenius americanus*)
Mallard (*Anas platyrhynchos*)
Mountain bluebird (*Sialia currucoides*)
Mourning dove (*Zenaida macroura*)[1]
Northern harrier (*Circus cyaneus*)
Northern pintail (*Anas acuta*)
Northern rough-winged swallow (*Stelgidopteryx serripennis*)
Red-tailed hawk (*Buteo jamaicensis*)
Red-winged blackbird (*Agelaius phoeniceus*)[1]
Ring-necked pheasant (*Phasianus colchicus*)[1]
Rock dove (*Columba livia*)[1]
Rough-legged hawk (*Buteo lagopus*)
Savannah sparrow (*Passerculus sandwichensis*)[1]
Say's phoebe (*Sayornis saya*)
Sharp-tailed grouse (*Pedioecetes phasianellus*)[1]
Short-eared owl (*Asio flammeus*)
Swainson's hawk (*Buteo swainsoni*)
Turkey vulture (*Cathartes aura*)
Upland sandpiper (*Bartramia logicauda*)
Vesper sparrow (*Pocecetes gramineus*)[1]

Table 5. Continued

Water pipit (*Anthus spinoletta*)
Western kingbird (*Tyrannus verticalis*)
Western meadowlark (*Sturnella neglecta*)[1]
Wilson's phalarope (*Phalaropus tricolor*)

[1]Potential poisoned oat consumer grouped into seed-eating guild.

[2]Analyzed by individual species.

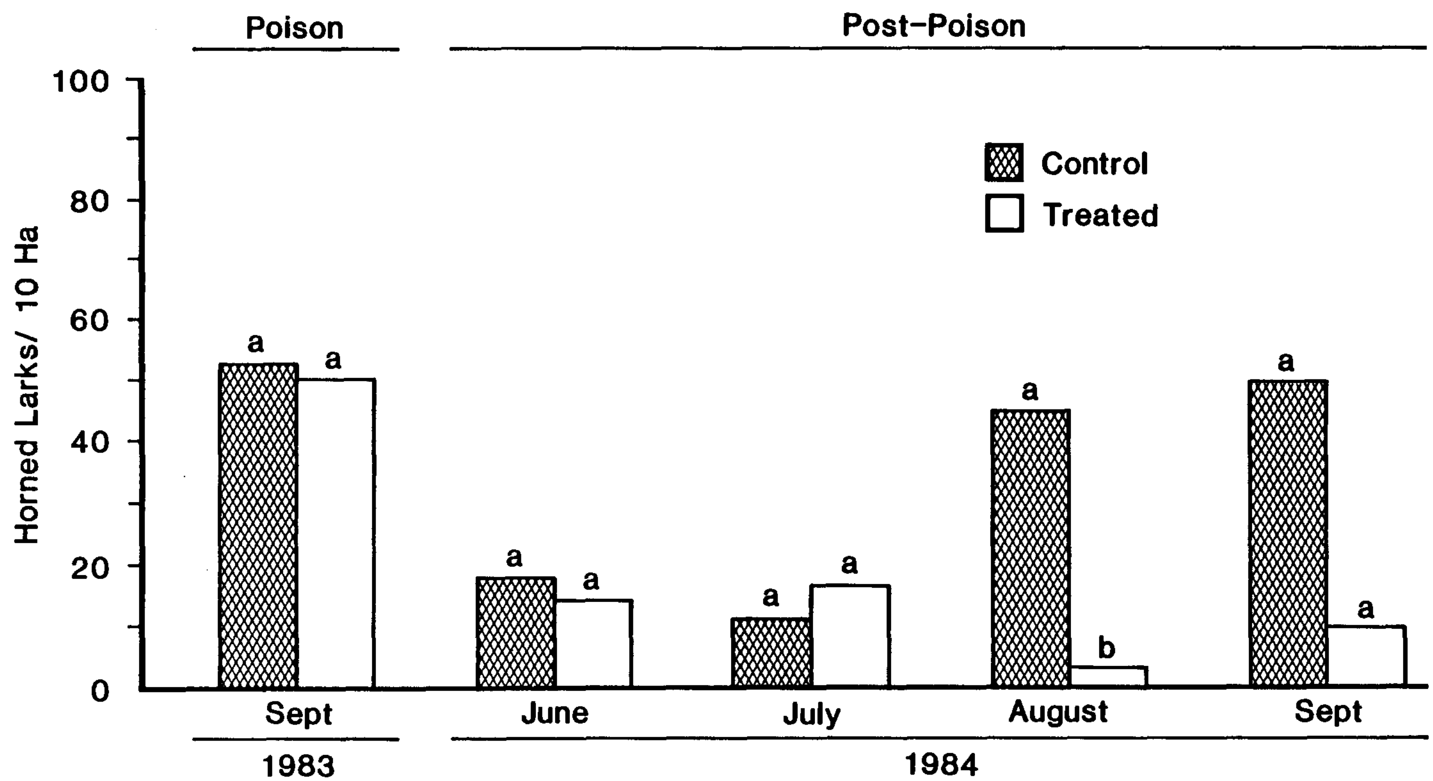

Fig. 6. Seasonal comparisons of horned lark relative densities on zinc phosphide treated and sites from initial treatment in September 1983 through September 1984. Adjusted means are from covariance analysis. Statistical analysis was conducted on posttreatment minus pretreatment. Means followed by the same letter by date are not significant at $\alpha = 0.20$ after F-protection at $\alpha = 0.10$.

Prairie dog sites treated with strychnine only in 1983 showed that horned lark densities were reduced 66% ($P = 0.109$) (Fig 7). From June through September 1984, after initial strychnine treatment, no differences in relative horned lark densities occurred between treated and control sites ($P > 0.20$), indicating no long-term impacts. Relative densities of horned larks for pretreatment and posttreatment and statistical analysis are presented in Appendix Tables 5, 6, 7, 8, and 9.

Strychnine with prebait reduced horned larks by 45% ($P = 0.128$) (Fig. 8). By June 1984, horned lark densities were the same on treated and control sites ($P = 0.746$). In July 1984, 33 horned larks/10 ha were observed on the controls while only 13/10 ha were on the treated sites ($P = 0.011$). In August, relative densities of horned larks on control sites were 81% higher (62/10 ha) than on the treated sites (12/10 ha) ($P = 0.002$). By September 1984, however, there were no differences in relative densities between treated and control sites ($P > 0.10$). Relative densities of horned larks for pretreatment and posttreatment with statistical analysis are presented in Appendix Tables 5, 6, 7, 8, and 9.

The impact of zinc phosphide on horned larks was not different from that of strychnine only ($P = 0.254$, Table 6). In June and July 1984, there was no difference between the effect of zinc phosphide and strychnine on horned larks ($P = 0.948$, and $P = 0.717$, respectively).

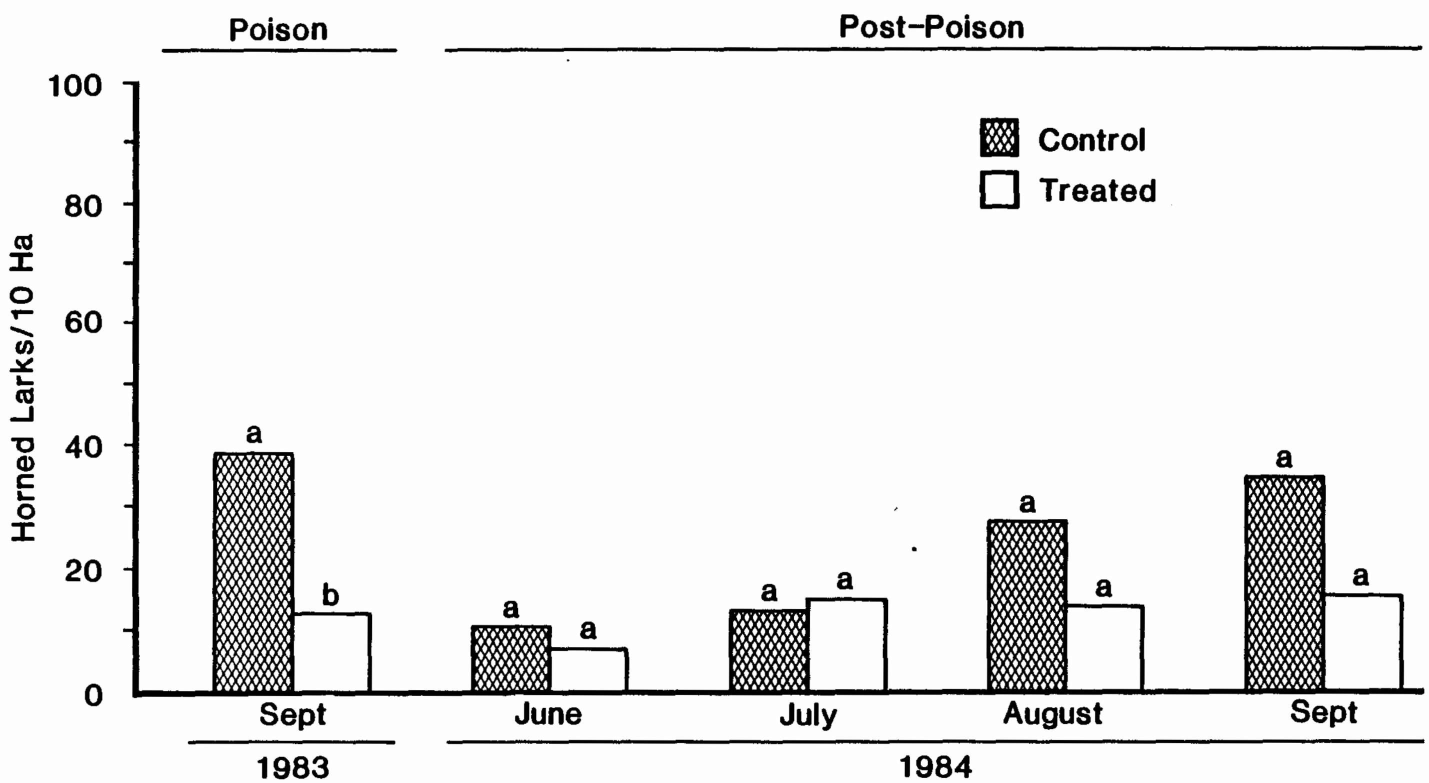

Fig. 7. Seasonal comparisons of horned lark relative densities on strychnine only treated and control sites from initial treatment in September 1983 through September 1984. Adjusted means are from covariance analysis. Statistical analysis was conducted on posttreatment minus pretreatment. Means followed by the same letter by date are not significant at α = 0.20 after F-protection at α = 0.10.

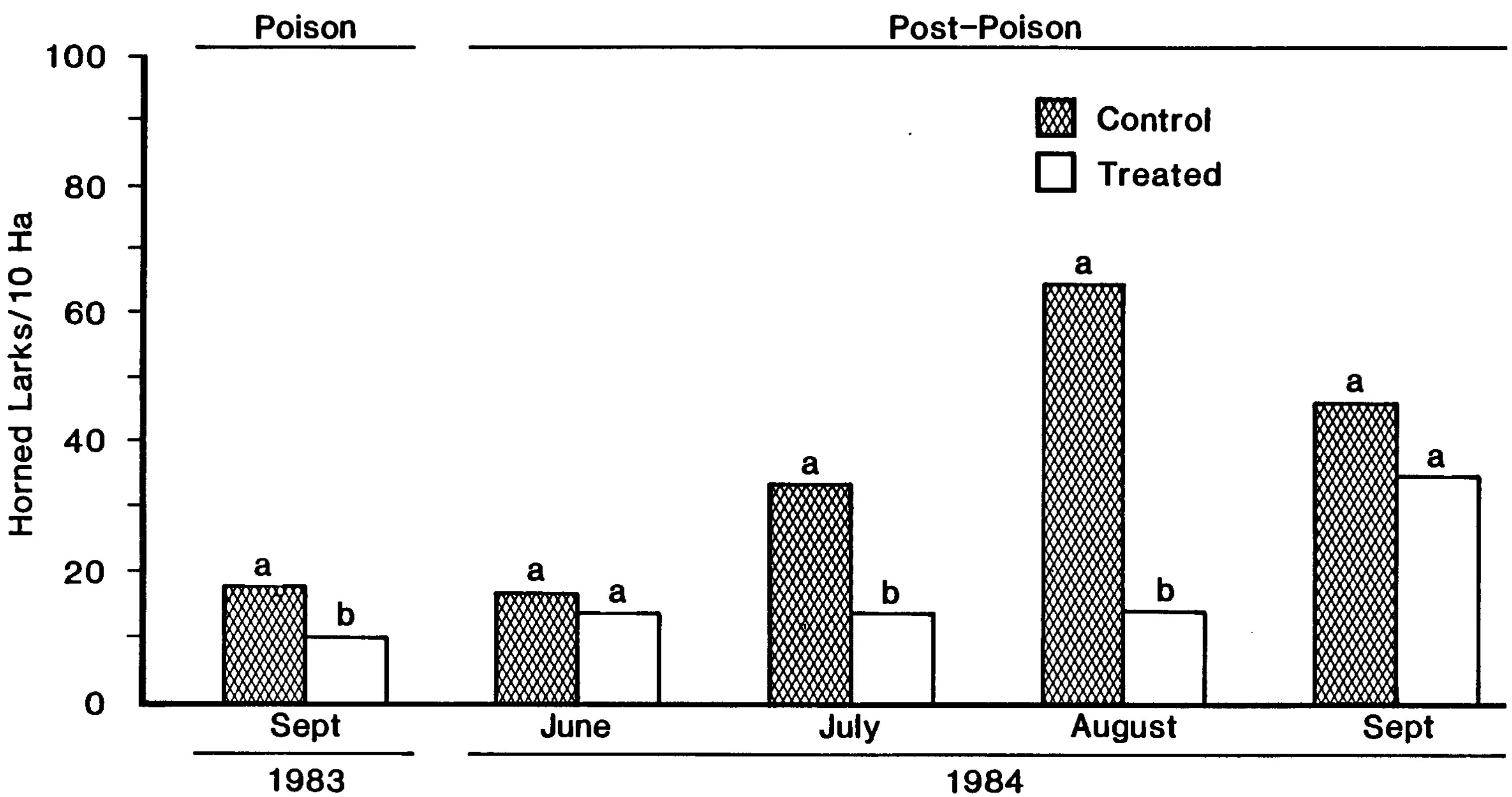

Fig. 8. Seasonal comparisons of horned lark densities on prebaited strychnine treated and control sites from initial treatment in September 1983 through September 1984. Adjusted means are from covariance analysis. Statistical analysis was conducted on posttreatment minus pretreatment. Means followed by the same letter by date are not significant at $\alpha = 0.20$ after F-protection at $\alpha = 0.10$.

Table 6. Comparison of effects of zinc phosphide (ZnP) with strychnine (S-9) only on horned lark relative densities/10 ha.

	Zinc Phosphide		Versus Strychnine	
	Adjusted Effect			
Period	ZnP[1]	S-9[1]	Main Effect[2]	Significance[3]
1983				
Sept	1±19	-30±19	31±19	0.254
1984				
June	- 5±7	- 4±7	- 1±7	0.948
July	- 6+5	- 2+5	4+5	0.717
August	-31±3	3±11	33±14	0.183
Sept	-38±20	-25±20	-13±20	NS[4]

[1]Effect adjusted through subtraction or analysis of covariance.

[2]Main effect calculated by difference of poisons.

[3]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance heterogeneity after a significant F-protection at α = 0.10 by analysis of variance or covariance.

[4]F-protection at α = 0.10.

In August 1984, the effect of zinc phosphide was greater than with strychnine ($P = 0.183$), however, in September 1984 no differences occurred between zinc phosphide and strychnine ($P < 0.10$).

A comparison of zinc phosphide to prebaited strychnine showed no difference in horned lark relative densities ($P = 0.280$) in September 1983 (Table 7). No differences were found between rodenticides in June 1984 ($P = 0.774$). During July and August of 1984 differences were observed between zinc phosphide and prebaited strychnine ($P = 0.020$ and $P = 0.062$, respectively). Zinc phosphide showed the least impact on horned lark densities compared to prebaited strychnine. However in September 1984, no differences between zinc phosphide and strychnine were found ($P > 0.10$).

Strychnine only and prebaited strychnine were compared in September 1983 and no difference ($P = 0.964$) was found (Table 8). In June 1984 there was a difference of 2 horned larks/10 ha between the 2 treatments ($P = 0.834$). Differences were observed in July (22 horned larks/10 ha) and August (87) 1984 ($P = 0.066$ and $P = 0.006$, 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 ($P > 0.10$).

Table 7. Comparison of effects of zinc phosphide (ZnP) with prebaited strychnine (PS-9) on horned larks relative densities/10 ha.

	Zinc Phosphide	Versus Prebaited Strychnine		
	Adjusted Effect			
Period	ZnP[1]	PS-9[1]	Main Effect[2]	Significance[3]
1983				
Sept	1±19	-29±19	30±10	0.280
1984				
June	- 5±7	- 2±7	- 2±7	0.774
July	6±5	-20±5	26±5	0.020
August	-31±3	-84±1	53±4	0.062
Sept[4]	-38±20	-32±20	- 6±20	NS[4]

[1]Effect adjusted through subtraction or analysis of covariance.

[2]Main effect calculated by difference of poisons.

[3]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance heterogeneity after a significant F-protection at α = 0.10 by analysis of variance or covariance.

[4]F-protection at α = 0.10.

Table 8. Comparison of effects of strychnine only (S-9) with prebaited strychnine (PS-9) on horned lark relative densities/10 ha.

	Strychnine	Versus Prebaited Strychnine		
	Adjusted Effect			
Period	S-9[1]	PS-9[1]	Main Effect[2]	Significance[3]
1983				
Sept	-30±19	-29±19	-1±19	0.964
1984				
June	- 4±7	- 2±7	-2±7	0.834
July	2±5	-20±5	22±5	0.066
August	3±11	-84±1	87±11	0.006
Sept[4]	-25±20	-32±20	7±20	NS[4]

[1]Effect adjusted throough subtraction or analysis of covariance.

[2]Main effect calculated by difference of poisons.

[3]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance heterogeneity after a significant F-protection at α = 0.10 by the analysis of variance or covariance.

[4]F-protection at α = 0.10.

GRANIVOROUS AVIAN GUILD

The remaining seed-eating birds were combined into a guild because of small sample sizes. In September 1983, no treatment effect ($P > 0.10$) was found on the seed-eating guild without horned larks. This was also true for June ($P = 0.754$), July ($P = 0.300$), and September ($P = 0.841$) of 1984. Additional data for the seed-eating guild is presented in Appendix Tables 10, 11, 12, and 14.

In August 1984, seed-eating bird densities on the zinc phosphide treated sites were similar ($P = 0.454$) to the controls (Fig. 9). On the strychnine control sites 5 birds/10 ha were found and on the treated sites 4 birds/10 ha were found ($P = 0.181$) (Fig. 10). 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 ($P = 0.030$) (Fig. 11). Additional information on pretreatment and posttreatment seed-eating bird densities can be found in Appendix Table 13.

In August 1984, the impact of rodenticides on the avian seed-eating guild indicated that the effective difference on the prebaited strychnine treatment was larger than the zinc phosphide (-30 birds/10 ha) ($P = 0.173$) and strychnine (-22) ($P = 0.011$) treatments (Table 9). Zinc phosphide and strychnine impacts on the seed-eating guild were similar (-8) ($P = 0.721$).

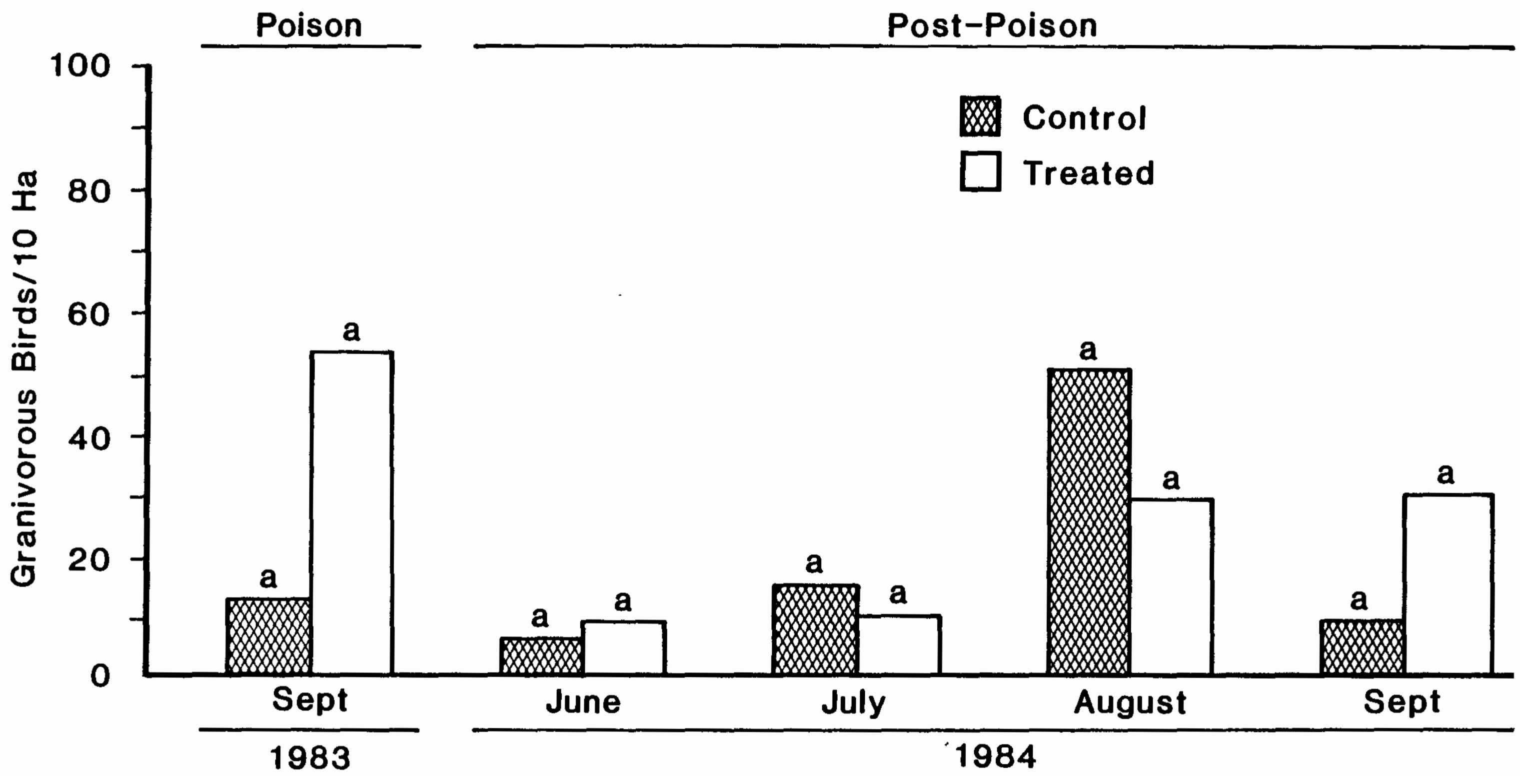

Fig. 9. Seasonal comparisons of seed-eating birds relative densities on zinc phosphide treated and control sites from initial treatment in September 1983 through September 1984. Adjusted means are from covariance analysis. Statistical analysis was conducted on posttreatment minus pretreatment. Means followed by the same letter by date are not significant at $\alpha = 0.20$ after F-protection at $\alpha = 0.10$.

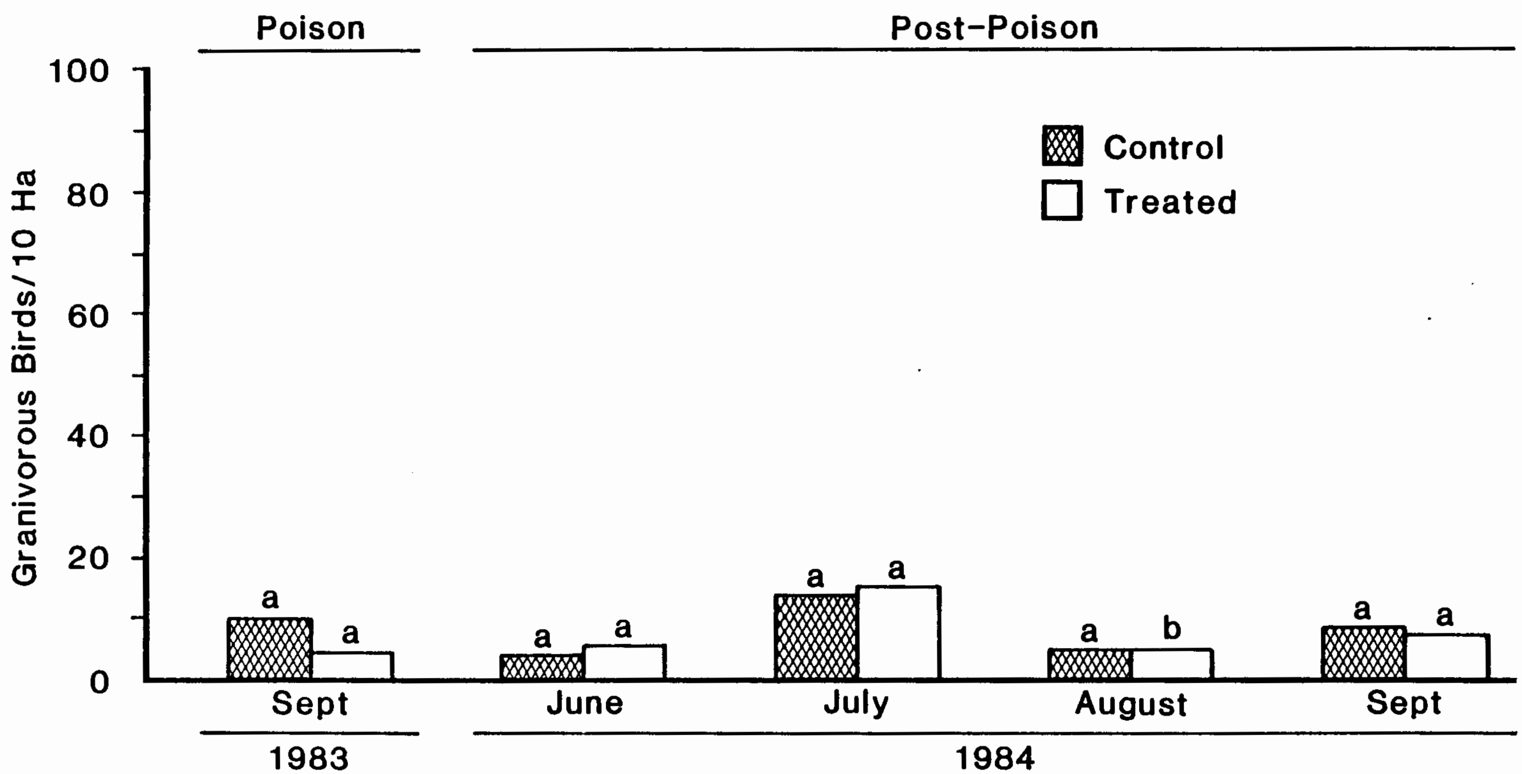

Fig. 10. Seasonal comparisons of seed-eating bird relative densities on strychnine only treated and control sites from initial treatment in September 1983 through September 1984. Adjusted means are from covariance analysis. Statistical analysis was conducted on posttreatment minus pretreatment. Means followed by the same letter by date are not significant at $\alpha = 0.20$ after F-protection at $\alpha = 0.10$.

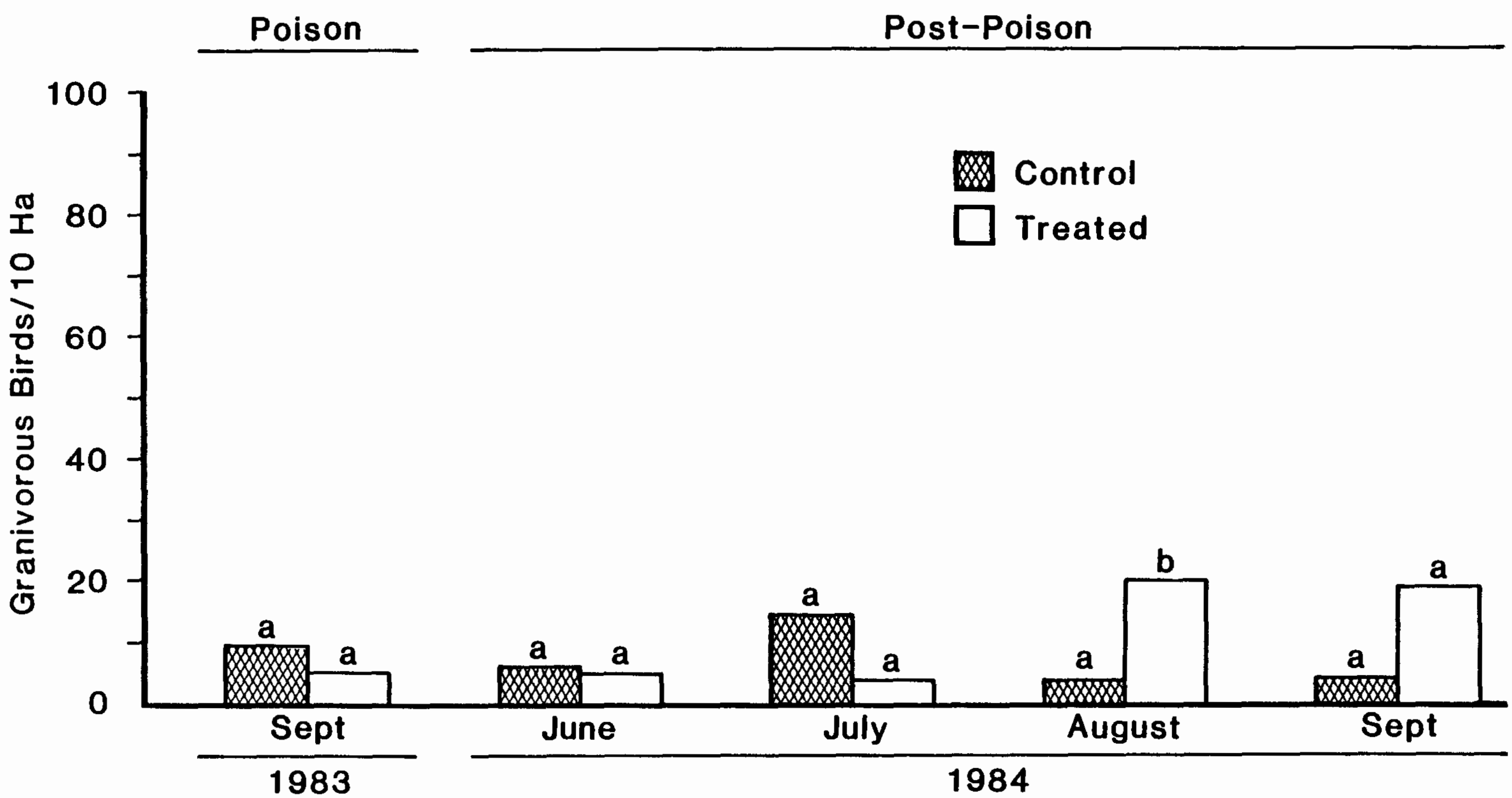

Fig. 11. Seasonal comparisons of seed-eating bird relative densities on prebaited strychnine treated and control sites from initial treatment in September 1983 through September 1984. Adjusted means are from covariance analysis. Statistical analysis was conducted on posttreatment minus pretreatment. Means followed by the same letter by date are not significant at $\alpha = 0.20$ after F-protection at $\alpha = 0.10$.

Table 9. Comparison of effects of zinc phosphide (ZnP) with strychnine only (S-9), zinc phosphide with prebaited strychnine (PS-9), and strychnine only with 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[1]	-18±7	-10±5	-18±5	-12±10	-10±3	-12±8
Main Effect[2]	-8±6		-30±8		-22±10	
Significance[3]	0.721		0.173		0.011	

[1]Effect adjusted through analysis of covariance.

[2]Main effect calculated by difference of poisons.

[3]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.

DISCUSSION

PRAIRIE DOG BURROWS

Black-tailed prairie dog burrow densities on the experimental colonies were representative for black-tailed prairie dog colonies in South Dakota and other western states. Other studies (Bailey 1926, Koford 1958, Uresk et al. 1981, O'Meilia et al. 1982, and Uresk and Bjugstad 1983) have reported similar burrow densities. Burrow activity showed trends, with high activity in the spring and lower in fall.

In this study zinc phosphide was effective in reducing the number of active burrows and was comparable to results of other studies (Tietjen 1976a, Knowles 1982, and Tietjen and Matschke 1982). The level of reduction in active burrows achieved with zinc phosphide in the fall of 1983 was adequate to maintain low populations of prairie dogs through 1984. When strychnine only was applied, burrow activity was reduced, but recruitment returned the number of active burrows to precontrol levels by July 1984. Prebait with strychnine application obtained burrow activity reductions in 1983, and maintained reduced populations through 1984.

Zinc phosphide was more effective than strychnine alone or prebaited strychnine in reducing prairie dogs. Burrow activity reductions obtained with strychnine were equal to reductions obtained with prebaited strychnine in 1983 and early 1984, but long-term results suggest the level of prairie dog control was greater with a prebait application. Other authors have also found that prebait was needed when using strychnine and zinc phosphide (Crabtree 1962, Tietjen 1976a, and Tietjen 1976b).

Level of prairie dog reductions achieved with prebaited strychnine allowed minimum prairie dog recovery while reductions in prairie dog activity with strychnine alone were inconsistent. Knowles (1982) stated that the intrinsic rate of growth (r) for prairie dogs in poisoned colonies was higher than normal. Prairie dog colonies with complete control reached precontrol densities in 5 or more years; when treatment was incomplete precontrol densities returned in 2 years.

BAIT CONSUMPTION

Zinc phosphide was consumed by prairie dogs more readily than strychnine with or without prebait. The amount of strychnine alone consumed by prairie dogs was not significantly different if prebait was used. The lack of a significant difference in strychnine consumption, even with greater activity reductions achieved with prebaited strychnine, is not easily explained. Results could reflect experimental error or unknown prairie dog behavior.

More bait remained on the prairie dog mounds after poisoning with strychnine than on mounds treated with zinc phosphide. Consumption of rodenticides by prairie dogs is related to the "taste factor" that accompanies strychnine and zinc phosphide, and the time factor involved before there is a toxic reaction after poison consumption (Crabtree 1962). Prebait was applied to increase the acceptance of a foreign food (grain bait), but prairie dogs consume less strychnine because of its bitter taste and fast toxic reaction, 5-20 minutes (Crabtree 1962). Rodents are attracted to the strong, pungent, phosphorous-like odor of zinc phosphide and more time is necessary before toxic reactions and death occur (Crabtree 1962) thus allowing more poisoned grain to be consumed.

BIRDS

HORNED LARK

Even though there was no immediate impact on horned larks by zinc phosphide, there was an impact by the 2 strychnine treatments. Strychnine is known for its avicidal abilities (Courtsal 1983), but little has been documented on its direct affects on birds. Direct losses were observed and horned lark carcasses were found on the poisoned towns prior to complete poison application. Decreased relative densities of horned larks on both strychnine treatments were a result of poison toxicity and the large quantities of strychnine grain that remained on the mounds after posttreatment. This excess strychnine treated grain was available to horned larks until bait disappearance. Hegdal and Gatz (1977a) found lethal strychnine doses to birds 2 months after poison application and significant reductions in horned lark populations in Wyoming.

Losses of horned larks from zinc phosphide were not as conspicuous because: (1) poison grain remaining was low; (2) birds have an adversion to black colored foods (Rudd and Genelly 1956); and (3) birds have a negative sensory (besides sight) response to zinc phosphide (Siegfried 1968). Reduced impacts by zinc phosphide on birds have also been reported by Tietjen (1976a), Tietjen and Matschke (1982), and Matschke et al. (1983).

There were indirect impacts on horned larks which resulted from habitat changes. In 1984 juveniles began to fledge and differences were observed between the control and treated sites. After treatment of prairie dog colonies in the fall of 1983, horned larks nested on what appeared to be potential optimum habitat in 1984. Optimum nesting habitat consists of semibare or heavily grazed situations (Pickwell 1931, Dubois 1935, Bent 1968, Gietzentanner 1970, Creighton 1974). Summer progressed, and prairie dogs were not available to graze the spring growth. Many grasses (cheatgrass brome and western wheatgrass) and forbs (prairie sunflower) had obtained heights above the line of sight of ground-dwelling birds. Plant biomass increase provided suitable habitat for western meadowlark, lark bunting, and chestnut-collared longspur (Giezentanner 1970).

Optimum habitat maintained by prairie dogs and other herbivores existed on the control sites throughout 1984 for horned larks. The low levels of prairie dog control on strychnine treated towns allowed surviving prairie dogs to limit vegetation and maintain optimum habitat for horned larks.

GRANIVOROUS AVIAN GUILD

No immediate impacts on granivorous seed-eating birds were found. Hegdal and Gatz (1977a) indicated that strychnine posed a threat to red-winged, yellow-headed (Xanthocephalus xanthocephalus), and Brewer's (*Euphagus cyancocephalus*) 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 1976a, Hegdal and Gatz 1977b).

CONCLUSIONS

Zinc phosphide provided the most efficient and ecologically sound control of prairie dogs. Both strychnine treatments had direct immediate effects on the horned lark populations. Where high levels prairie dog reductions were achieved, indirect impacts were found on horned larks through habitat changes.

I recommend the discontinued use of strychnine for black-tailed prairie dog control as applied in this study. If strychnine use is continued managers should consider a reduction in the strychnine dosage by 1/2, from 8 to 4 g, until proper dosage research provides more reliable data. Prebait should be used if long-term prairie dog control is desired.

Suggestions for further research include: (1) lethal dose determination for strychnine and zinc phosphide for target and nontarget species; (2) long-term studies involving the movement of zinc phosphide and strychnine through the environment; and (3) a more reliable, efficient, and practical index for estimating prairie dog numbers. Plugged burrows are a measure of activity, but do not estimate prairie dog numbers.

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APPENDIX

Appendix Table 1. Active burrows/ha of black-tailed prairie dogs (mean ± standard error) for pre- and postpoison treatment on treated and control sites.

Treatment	September 1983 Pretreatment	September 1983 Posttreatment	Adjusted Main Effect[1]	Significance[2]
Zinc phosphide (prebait)				
Treated	55±16	2±1	-45±9	0.014
Control	59±9	48±9		
Strychnine				
Treated	42±6	15±10	-14±9	0.167
Control	25±5	24±1		
Strychnine (prebait)				
Treated	55±7	7±3	-23±11	0.038
Control	54±21	30±13		

[1]Main effec- (mean ± standard error) adjusted using the pretreatment as the covariate in the analysis of covariance.

[2]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance heterogeneity after significant F-protection α = 0.10 was obtained in analysis of covariance.

Appendix Table 2. Active burrows/ha of black-tailed prairie dogs (mean ± standard error) for pre- and postpoison treatment on treated and control sites.

Treatment	June 1984 Pretreatment	June 1984 Posttreatment	Adjusted Main Effect[1]	Significance[2]
Zinc phosphide (prebait)				
Treated	101±4	4±2	-86±5	0.002
Control	82±14	81±11		
Strychnine				
Treated	113±23	58±19	-22±11	0.177
Control	68±13	60±11		
Strychnine (prebait)				
Treated	113±22	23±5	-82±13	0.019
Control	109±33	104±32		

[1]Main effect (mean ± standard error) adjusted using the pretreatment as the covariate in the analysis of covariance

[2]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance heterogeneity after significant F-protection α = 0.10 was obtained in analysis of covariance.

Appendix Table 3. Active burrows/ha of black-tailed prairie dogs (mean ± standard error) for pre- and postpoison treatment on treated and control sites.

Treatment	July 1984 Pretreatment	July 1984 Posttreatment	Adjusted Main Effect[1]	Significance[2]
Zinc phosphide (prebait)				
Treated	99±10	5±2	-59±11	0.006
Control	85±22	64±9		
Strychnine				
Treated	101±27	66±27	+10±8	0.706
Control	53±8	53±6		
Strychnine (prebait)				
Treated	102±21	15±2	-68±29	0.083
Control	91±26	82±30		

[1]Main effect (mean ± standard error) adjusted using the pretreatment as the covariate in the analysis of covariance.

[2]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance heterogeneity after significant F-protection α = 0.10 was obtained in analysis of covariance.

Appendix Table 4. Active burrows/ha of black-tailed prairie dogs (mean ± standard error) for pre- and postpoison treatment on treated and control sites.

Treatment	September 1984		Adjusted Main Effect[1]	Significance[2]
	Pretreatment	Posttreatment		
Zinc phosphide (prebait)				
Treated	55±16	14±4	-43±7	0.014
Control	59±9	58±10		
Strychnine				
Treated	42±6	41±13	- 7±18	0.637
Control	25±5	46±5		
Strychnine (prebait)				
Treated	55±7	17±2	-77±38	0.057
Control	54±21	93±36		

[1]Main effect (mean ± standard error) adjusted using the pretreatment as the covariate in the analysis of covariance.

[2]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance heterogeneity after significant F-protection α = 0.10 was obtained in analysis of covariance.

Appendix Table 5. Relative densities of horned larks/10 ha (mean ± standard error) for pre- and postpoison treatment of zinc phosphide, strychnine only, and prebaited strychnine on treated and control sites.

Treatment	September 1983		Adjusted Density[1]	Main Effect[2]	Significance[3]
	Pretreatment	Posttreatment			
Zinc phosphide (prebait)					
Treated	35±14	44±14	10±4	1±18	0.977
Control	24±10	43±16	18±16		
Strychnine					
Treated	24±20	4±2	-19±19	-30±18	0.109
Control	45±25	35±16	-10±7		
Strychnine (prebait)					
Treated	59±14	12±6	-49±11	-30±18	0.128
Control	135±40	41±4	-94±37		

[1]Posttreatment minus pretreatment adjustment was used to adjust data.

[2]Treated mean minus control mean of posttreatment values used to adjust main effect.

[3]Probabilities calculated for contrasts in randomization test (α = 0.20) based on various heterogeneity after significant F-protection α = 0.10 was obtained in analysis of variance.

Appendix Table 6. Relative densities of horned larks/10 ha (mean ± standard error) for pre- and postpoison treatment of zinc phosphide, strychnine only, and prebaited strychnine on treated and control sites.

Treatment	June 1984		Adjusted Density[1]	Main Effect[2]	Significance[3]
	Pretreatment	Posttreatment			
Zinc phosphide (prebait)					
Treated	14±4	10±6	-4±3	-5±7	0.479
Control	13±2	14±2	2±4		
Strychnine					
Treated	21±4	6±2	-15±4	-4±7	0.542
Control	23±4	10±2	-14±1		
Strychnine (prebait)					
Treated	48±12	18±6	-30±11	-2±7	0.746
Control	45±10	20±4	-25±12		

[1]Posttreatment minus pretreatment adjustment was used to adjust data.

[2]Treated mean minus control mean of posttreatment values used to adjust main effect.

[3]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance heterogeneity after significant F-protection α = 0.10 was obtained in analysis of variance.

Appendix Table 7. Relative densities of horned larks/10 ha (mean ± standard error) for pre- and postpoison treatment of zinc phosphide, strychnine only, and prebaited strychnine areas on treated and control sites.

Treatment	July 1984		Adjusted Density[1]	Main Effect[2]	Significance[3]
	Pretreatment	Posttreatment			
Zinc phosphide (prebait)					
Treated	12±4	10±7	16±5	6±6	0.486
Control	29±10	13±2	10±4		
Strychnine					
Treated	14±6	10±3	14±2	2±1	0.869
Control	19±4	11±2	13±4		
Strychnine (prebait)					
Treated	29±6	16±6	13±3	-20±9	0.011
Control	37±6	41±10	33±6		

[1]Adjusted density (mean ± standard error) adjusted using the pretreatment as the covariate in the analysis of covariance.

[2]Main effect is calculated by subtracting the posttreatment control mean from the posttreatment treated mean.

[3]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance heterogeneity after significant F-protection α = 0.10 obtained in analysis of covariance.

Appendix Table 8. Relative densities of horned larks/10 ha (mean ± standard error) for pre- and postpoison treatment of zinc phosphide, strychnine only, and prebaited strychnine areas on treated and control sites.

Treatment	August 1984 Pretreatment	August 1984 Posttreatment	Adjusted Density[1]	Main Effect[2]	Significance[3]
Zinc phosphide (prebait)					
Treated	20±12	3±1	6±1	-31±3	0.190
Control	25±14	41±9	45±2		
Strychnine					
Treated	22±7	9±4	13±3	3±2	0.846
Control	37±3	28±8	26±8		
Strychnine (prebait)					
Treated	33±8	15±8	12±0	-84±2	0.002
Control	42±5	113±21	62±1		

[1]Adjusted density (mean ± standard error) adjusted using the pretreatment as the covariate in the analysis of covariance.

[2]Main effect is calculated by subtracting the posttreatment control mean from the posttreatment treated mean.

[3]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance heterogeneity after significant F-protection α = 0.10 in the analysis of covariance.

Appendix Table 9. Relative densities of horned larks/10 ha (mean ± standard error) for pre- and postpoison treatment of zinc phosphide, strychnine only, and prebaited strychnine areas on treated and control sites.

	September 1984				
Treatment	Pretreatment	Posttreatment	Adjusted Density[1]	Main Effects[2]	Significance[3]
Zinc phosphide (prebait)					
Treated	34±16	4±2	30±14	-38±20	NS
Control	25±10	42±13	17±10		
Strychnine					
Treated	24±19	8±3	-16±16	-24±20	NS
Control	45±25	32±11	-13±14		
Strychnine (prebait)					
Treated	60±15	38±26	-22±16	-32±20	NS
Control	136±41	70±6	-66±39		

[1]Posttreatment minus pretreatment adjustment was used to adjust data.

[2]Treated mean minus control mean of posttreatment values used to adjust main effect.

[3]No treatment effect occurred in the anlysis of variance at α = 0.10, F-protection levels, therefore no comparisons of contrasts.

Appendix Table 10. Relative densities of seed-eating birds/ha (mean ± standard error) for pre- an postpoison treatment of zinc phosphide, strychnine only, and prebaited strychnine areas on treated and control sites.

	September 1983				
Treatment	Pretretment	Posttreatment	Adjusted Density[1]	Main Effect[2]	Significance[3]
Zinc phosphide (prebait)					
Treated	31±6	61±36	30±32	44±15	NS
Control	22±6	17±8	- 5±12		
Strychnine					
Treated	8±7	2±2	- 6±8	- 3±15	NS
Control	1±1	5±3	3±2		
Strychnine (prebait)					
Treated	4±3	4±4	0±5	- 4±15	NS
Control	8±8	8±4	0±12		

[1]Posttreatment minus pretreatment adjustment was used to adjust data.

[2]Treated mean minus control mean of posttreatment values used to adjust main effect.

[3]No treatment effect occurred in the analysis of variance $\alpha = 0.10$, F-protection levels, therefore, no comparisons of contrasts.

Appendix Table 11. Relative densities of seed-eating birds/10 ha (mean ± standard error) for pre- and postpoison treatment of zinc phosphide, strychnine only, and prebaited strychnine areas on treated and control sites.

Treatment	June 1984		Adjusted Density[1]	Main Effect[2]	Significance[3]
	Pretreatment	Posttreatment			
Zinc phosphide (prebait)					
Treated	13±4	10±2	-3±2	3±3	NS
Control	8±3	7±2	-1±1		
Strychnine					
Treated	5±2	5±2	0±2	2±3	NS
Control	6±3	3±1	-3±2		
Strychnine (prebait)					
Treated	8±4	6±1	-2±4	0±3	NS
Control	3±1	6±4	3±5		

[1]Posttreatment minus pretreatment adjustment was used to adjust data.

[2]Treated mean minus control mean of posttreatment values used to adjust main effect.

[3]No treatment effect occurred in the analysis of variance $\alpha = 0.10$, F-protection levels, therefore, no comparisons of contrasts.

Appendix Table 12. Relative densities of seed-eating birds/10 ha (mean ± standard error) for pre- and postpoison treatment of zinc phosphide, strychnine only, and prebaited strychnine area on treated and control sites.

Treatment	July 1984		Adjusted Density[1]	Main Effect[2]	Significance[3]
	Pretreatment	Posttreatment			
Zinc phosphide (prebait)					
Treated	15±5	19±4	4±0	-6±4	NS
Control	16±5	25±14	9±9		
Strychnine					
Treated	5±3	7±3	2±1	3+4	NS
Control	4±0	4±1	0±0		
Strychnine (prebait)					
Treated	11±5	6±4	5±1	1+4	NS
Control	5±1	7±1	2±2		

[1]Posttreatment minus pretreatment adjustment was used to adjust data.

[2]Treated means minus control mean of posttreatment values used to adjust main effect.

[3]No treatment effect occurred in the analysis of variance $\alpha = 0.10$, F-protection levels, therefore, no comparisons of contrasts.

Appendix Table 13. Relative Densities of seed-eating birds/10 ha (mean ± standard error) for pre- and postpoison treatment of zinc phosphide, strychnine only, and prebaited strychnine areas on treated and control sites.

Treatment	August 1984 Pretreatment	August 1984 Posttreatment	Adjusted Density[1]	Main Effect[2]	Significance[3]
Zinc phosphide (prebait)					
Treated	12±6	31±11	28±8	-22±22	0.454
Control	8±5	43±23	50±2		
Strychnine					
Treated	13±6	4±2	4±1	0±4	0.181
Control	5±2	5±1	4±1		
Strychnine (prebait)					
Treated	6±2	12±7	20±1	17±4	0.030
Control	10±3	5±4	3±2		

[1]Adjusted density (mean ± standard error) adjusted using the pretreatment as the covariate in the analysis of covariance.

[2]Main effect is calculated by subtracting the posttreatment control mean from the posttreatment treated mean.

[3]Probabilities calculated for contrasts in randomization test (α = 0.20) based on variance hetergeneity after significant F-protection α = 0.10 obtained in analysis of covariance.

Appendix Table 14. Relative densities of seed-eating birds/10 ha (mean ± standard error) for pre- and postpoison treatment of zinc phosphide, strychnine only, and prebaited strychnine areas on treated and control sites.

Treatment	September 1984		Adjusted Density[1]	Main Effect[2]	Significance[3]
	Pretreatment	Posttreatment			
Zinc phosphide (prebait)					
Treated	31±6	39±26	8±22	25±12	NS
Control	22±6	14±6	-8±8		
Strychnine					
Treated	8±6	5±2	-3±3	3+12	NS
Control	1±1	2±1	1±2		
Strychnine (prebait)					
Treated	4±2	14±10	10±12	13±12	NS
Control	8±8	1±0	-7±8		

[1]Posttreatment minus pretreaatment adjustment was used to adjust data.

[2]Treated mean minus control mean of posttreatment values used to adjust effect.

[3]No treatment effect occurred in the analysis of variance $\alpha = 0.10$, F-protection levels, therefore, no comparisons of contrasts.