Comparison of methods to estimate population densities of black-tailed prairie dogs

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Abstract Recent reintroduction of the black-footed ferret (*Mustela nigripes*) in west-central South Dakota has focused new attention on black-tailed prairie dogs (*Cynomys ludovicianus*), because prairie dog colonies provide essential habitat for ferrets. Currently, management agencies are assessing prairie dog populations by counting active burrows, a technique that is attracting criticism. We correlated active and total burrow counts with prairie dog mark–recapture population estimates from 12 colonies located in Badlands National Park and adjacent Buffalo Gap National Grassland. We also correlated visual counts of prairie dogs and counts of mounds from aerial photographs with mark–recapture estimates to assess an alternative method to index populations. We found no significant relationships ($P > 0.05$) with any form of active burrow or total burrow counts (ground or aerial) using the linear model $Y = a + bX$. However, visual counts of prairie dogs, using maximum rather than mean values, on 4-ha plots were significantly related ($P < 0.0138$). The best model was $Y = 3.04 + 0.40X$, where Y is the maximum visual count and X is the estimated population density. The inverse of this equation $X = (Y - 3.04)/(0.40)$, could be used to index numbers of black-tailed prairie dogs from visual counts under conditions similar to those encountered in this study. An 8-point protocol for making visual counts is provided.

Key words burrow counts, *Cynomys ludovicianus*, mark–recapture, *Mustela nigripes*, population density, South Dakota, visual count

Prairie dog (*Cynomys* spp.) colonies provide essential habitat for the endangered black-footed ferret (*Mustela nigripes*). Currently found only in captivity and on experimental release sites in Wyoming, South Dakota, and Montana, black-footed ferrets prey almost exclusively on prairie dogs and live in prairie dog burrows (Hillman 1968). Reestablishing viable populations of black-footed ferrets, therefore, depends on establishing and maintaining adequate numbers of prairie dogs within properly distributed colonies of optimum size (Houston et al. 1986).

The recent black-footed ferret reintroduction into Conata Basin in west-central South Dakota has prompted managers of 2 agencies (U.S. Dep. Agric. For. Serv. [Buffalo Gap Natl. Grassland] and Natl. Park Serv. [Badlands Natl. Park]) to reassess methods of determining sizes of populations of black-tailed prairie dogs (*C. ludovicianus*). Most agencies rely on a protocol developed by Biggins et al. (1993) to assess black-footed ferret habitat. The protocol is based on population estimates derived from counting numbers of active prairie dog burrows. Justification for this was a set of unpublished data that reported fair and good relationships between counts of active burrows and black- and white-tailed prairie dogs (*C. leucurus*), respectively (Biggins et al. 1993). Powell et al. (1994) suggested that counts of active burrows may not be a reliable indicator of black-tailed prairie dog populations. Menkens et al. (1988) examined relationships between populations estimated by

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mark-recapture and total burrow counts and reported that white-tailed prairie dog density was not significantly related to burrow density. However, Fagerstone and Biggins (1986) and Menkens et al. (1990) reported high correlation coefficients in comparing visual counts of white-tailed prairie dogs with mark-recapture densities.

The efficacy of indirect and direct sample methods has not been determined for black-tailed prairie dogs. King (1955), Powell et al. (1994), and Hoogland (1995) did not find relationships between burrow counts and the number of animals in a colony, but their conclusions were not based on quantitative assessments. Only Knowles (1982) reported that, although a high correlation ($r^2 = 0.942$) existed between total population size (based on intensive trapping) and maximum visual counts, they found little correlation ($r^2 = 0.004$) between total population size and unplugged burrow counts.

Differences in social behavior and colony structure between black- and white-tailed prairie dogs, differences in vegetation composition among habitats of the 2 species, and lack of a strong data base relative to active burrow counts led to the development of this study. We examined relationships among population estimates from mark-recapture techniques with visual counts, active and total burrow counts derived by ground transects (see Biggins et al. 1993), and aerial surveys, all within the same experimental design.

Study area

We conducted the study in the Conata Basin area of west-central South Dakota on lands administered by both the U.S. Department of Agriculture (USDA) Forest Service (Buffalo Gap Natl. Grassland) and the National Park Service (Badlands Natl. Park). The climate is semi-arid with an average (40 yr) annual precipitation of 39.9 cm, most of which falls during the growing season in locally severe thunderstorms. Mean annual temperature is 10.3°C, and monthly means range from -4.6°C in January to 25.5°C in July (Nat. Oceanic and Atmos. Adm. 1993). Weather data are from the town of Interior, South Dakota, on the east edge of the study area. Study plots were located on a gently sloping alluvial plain lying between the White River on the south and an actively eroding badlands wall on the north. Topography is level but dissected by small drainages running north to south. Small, isolated badland buttes are scattered throughout. Soils are young and poorly developed with textural classes dominated by clay.

Vegetation is mixed prairie, dominated by western wheatgrass (*Agropyron smithii*), buffalograss (*Buchloe dactyloides*), and blue grama (*Bouteloua gracilis*). Excessive herbivory causes a decline of western wheatgrass, coupled with an increase in the 2 shortgrasses, buffalograss and blue grama; these in turn decline with continued disturbance, and annual forbs such as Patagonian plantain (*Plantago patagonica*), fetid marigold (*Dyssodia papposa*), and snow-on-the-mountain (*Euphorbia marginata*) invade a site. An expanding prairie dog colony typically has an interior core dominated by annual forbs and a peripheral ring dominated by shortgrasses (Cincotta et al. 1989).

Methods

We selected 12 prairie dog colonies for study in 1993; 8 were located in Buffalo Gap National Grassland and 4 were located in Badlands National Park. Colonies in National Grassland were open to prairie dog shooters; those in the National Park were not. We classed 5 of the colonies selected as "new," i.e., with a relatively intact buffalograss-blue grama component, and 7 as "old," i.e., dominated by annual forbs. We selected colonies with varying harvest regimes and different ages to ensure we sampled a wide range of probable prairie dog densities. Prairie dogs in 2 study colonies in Badlands National Park, 1 old and 1 new, were controlled during autumn, 1993; 2 substitute colonies, 1 on National Grassland (new) and 1 within the Park (old) were selected. A 200 x 200 m macroplot (4 ha) was established on each of the 12 colonies.

Mark–recapture

A mark-recapture grid was placed within each of the 12 macroplots. Numbered wooden stakes were placed at 16.7 m in a 10 x 10 grid in the middle of the macroplot, leaving a buffer strip of 25 m around the trap grid. Staked locations were prebaited with a commercial horse feed composed of corn, oats, barley, and molasses. The following day, live traps (61 x 23 x 20 cm) were placed at each stake, left open, and prebaited again. Traps were set on the third day, and animals were trapped for 4-5 consecutive mornings (until an estimated equilibrium population density was reached). Traps were set from 0700 to 0800 and left open for about 4 hours. Animals were marked with green acrylic paint and released. Shooting of prairie dogs on colonies within National Grassland was prohibited during trapping and visual counting periods to facilitate population closure (Menkens and Anderson 1993). Trapping activities were conducted from late June through August. The program CAPTURE (Rexstad and Burnham 1991) was used to estimate abundance. Mark-recapture estimates were assumed to be unbiased estimates of population densities (Seber 1986).

Visual counts

We conducted visual counts, using binoculars (7 x 35 mm) immediately before or within 1 week after trapping. Counts were made from a blind, a 3-m high observation platform on the southeast corner of the macroplot. Plot boundaries were delineated using fluorescent orange stakes. Prairie dogs on each macroplot were counted 4 consecutive times. Observers entered the blind at about 0700 and waited 30 minutes before beginning the first count and 15 minutes between counts. Counts were made for 3 consecutive days.

In visual counts the assumption is made that the probability of counting individuals is equal for all plots (Menkens et al. 1990). If obstructions (i.e., microrelief, vegetation height, etc.) vary among plots, this assumption may not be met. We used 2 approaches to assess the impact of vegetation and other obstructions on visual counts. First, we estimated vertical vegetation density using the Robel technique (Robel et al. 1970). Four readings were taken at each of 60 points on each 4-ha plot. Then, visibility was tested with a known number of "artificial" dogs (1-quart plastic bottles painted brown) placed in both a systematic and random pattern on ≥6 macroplots with different vegetation characteristics. Observers (who were not involved in bottle placement) made 3 counts of each pattern. We then analyzed counts to determine the relationships between vegetation density and random and systematic counts.

Second, we calculated correction factors for obstructions, using the method developed by Menkens et al. (1990). We selected vegetation density of 8 Robel divisions (20.3 cm) as one that would potentially interfere with visual counting of prairie dogs. The percentage of Robel pole readings ≥8 in each colony was our estimate of obstruction. Visual counts were corrected using the formula developed by Menkens et al. (1990).

Burrow and mound counts

Burrow or mound counts were conducted on all 12 macroplots by (1) strip-transect ground counts, (2) low-level color videography, and (3) low-level (1:4,000) aerial color infrared photography.

We adopted the Biggins et al. (1993) protocol for conducting strip-transect burrow counts. Sampling via transects was elected over total counts to conform to the protocol. A Rolatape® wheel, fitted with a 3-m piece of electrical conduit with wires hanging from conduit ends, was used to sample transects. Burrows were included if >50% of the opening was within the transect swath. We counted burrows with diameters ≥7 cm and deep enough so the ends were not visible. Burrows were identified as active, inactive, mounded, and unmounded, as defined and described by Biggins et al. (1993). Burrows were considered active if fresh prairie dog scat was found within 0.5 m of the opening.

Prior to this study, low-level videography had not been used to count mounds. A Forest Service fixed-wing aircraft with a belly-mounted video system recorded video images of 2 preselected colonies in 1993. We attempted to delineate mounds through playback of the images on high-resolution monitors.

Aerial photography (1:16,000) has been used to sample 5-year changes in mound densities in the Conata Basin-Badlands area (Schenbeck and Myhre 1986). During the summer of 1993, we acquired photography at a planned scale of 1:4,000 of the areas encompassing the 12 macroplots. We used color infrared film because of its ability to penetrate haze and its superior color contrast between living vegetation and bare soil (Schenbeck and Myhre 1986). After an initial training period using the photographs while walking over the colonies, we counted total mounds using macroscopic techniques.

Statistical analyses

Regression and correlation analyses were conducted using population estimates from mark-recapture as the independent variable (X) against the following dependent variables (Y): maximum visual counts, mean visual counts, mound counts from 1:4,000 aerial photos, active mounded burrows from ground counts, total active burrows (mounded and unmounded) from ground counts, and total mounds from ground counts. Differences in slopes (b) between years were examined using analysis of covariance. Paired *t*-tests were used for all between-year comparisons with data from only those 10 colonies for which we had data for both years. Prediction and calibration intervals were determined for the selected model following procedures by Graybill (1976). All statistical inferences were made at $\alpha = 0.05$.

Results and discussion

Visual counts

Mark-recapture density estimates of black-tailed prairie dogs ranged from 8 to 28 per hectare in 1993 and from 8 to 41 per hectare in 1994 (Table 1). These are in general agreement with the 14-22 per hectare (May counts of adults and yearlings) reported from other areas in South Dakota (Hoogland 1995).

Table 1. Mean ($\bar{x}$) mark-recapture population estimates, with standard errors (SE) generated by CAPTURE, of black-tailed prairie dogs on colonies in the South Dakota badlands, 1993 and 1994, (No./4-ha plot).

	1993		1994	
Colony	$\bar{x}$	SE	$\bar{x}$	SE
1	112	3.2	125	14.3
2	68	2.9	45	9.0
3	41	5.3	46	14.4
4	84	5.9	32	12.0
5	60	1.9		
6	58	3.1		
7	35	3.5	66	12.9
8	63	6.1	98	5.9
9	53	5.2	116	12.6
10	50	3.3	184	23.2
11	39	6.4	91	18.5
12	32	5.5	29	11.1
13			61	15.1
14			166	19.2

Examination of r^2, SEs, and distribution of residuals all indicated that linear models were appropriate. Correlations between visual counts and mark-recapture estimates were strong (Table 2). Within visual counts, maximum counts resulted in lower SEs and higher r^2. Both years and pooled estimates also were nonsignificant. Mean count relationships, although not significant in 1994 or for pooled estimates, were significant in 1993 (Table 2). Similar results were reached by Knowles (1982). Fagerstone and Biggins (1986), working with white-tailed prairie dogs, also found that maximum counts yielded better correlations with mark-recapture data than did mean counts.

Slopes (b), indicative of population density as a function of visual counts, were similar between years for mean counts (ANCOVA, $F = 2.74$; 1, 20 df; $P = 0.113$) and for maximum counts (ANCOVA, $F = 3.39$; 1, 20 df; $P = .081$), hence data were pooled.

The 1994 linear model, based on maximum visual counts (Fig. 1), was the most precise model. The r^2 indicated that 79% of the variation in the population could be accounted for by maximum visual counts, which was higher than either the 1993 or pooled forms. Standard error of the regression also was lower in 1994 than 1993 for the pooled linear model.

From a management standpoint, however, the pooled linear model (Fig. 1) may be best for predictive purposes because it accounts for some year-to-year variation. Differences in population structure existed between years. Although the mean number of animals trapped per plot was similar (49 in 1993 and 51 in 1994; $t = -0.20$, 9 df, $P = 0.847$), adults made up 70% of the total in 1993 and only 35% in 1994. Differences between sightability of adults and juveniles may exist or behavior may be altered by differences in population structure that affect counts and thereby population-count relationships.

Table 2. Relationships between estimated black-tailed prairie dog populations via mark-recapture (Y) and maximum and mean visual counts, aerial burrow counts, and ground burrow counts (X) using the linear model (Y = a + bX) on colonies in the South Dakota badlands in 1993 and 1994.

Variable	**Year**	n	**a**	**b**	r^2	**SE**	F	P
Visual Counts								
Max.[a]	93	12	2.61	0.50	47.0	3.14	8.88	0.0138
Max.	94	12	1.33	0.43	79.0	2.99	37.54	0.0001
Max.	Pooled	24	3.04	0.40	64.6	3.15	40.18	< 0.0001
$\bar{x}$[b]	93	12	2.95	0.23	22.1	2.56	2.84	0.1227
$\bar{x}$	94	12	1.38	0.30	72.2	2.52	25.93	0.0005
$\bar{x}$	Pooled	24	2.00	0.28	60.1	2.44	33.23	< 0.0001
Aerial Counts								
Mounded	93	10	31.04	−0.11	0.1	15.71	0.01	0.9109
Ground Counts								
Active Mounds[c]	93	12	74.57	0.26	0.2	30.39	0.03	0.8767
Active Mounds	94	12	46.63	0.21	2.7	16.98	0.28	0.6106
Total Active[d]	93	12	196.70	0.55	0.3	56.62	0.03	0.8591
Total Active	94	12	99.84	1.31	9.6	54.13	1.06	0.3270
Total Mounds	93	12	205.12	0.65	0.4	55.82	0.05	0.8318
Total Mounds	94	12	212.12	0.75	2.4	64.22	0.25	0.6309

[a] Includes the maximum number counted in any 1 trial over the 3-day counting period with 4 counts made each day.

[b] Mean of 12 counts; 3 days with 4 counts each day.

[c] Includes mounded burrows only; active determined via Biggins et al. (1993) protocol.

[d] Includes both mounded and unmounded active burrows.

Sightability tests revealed no relationships (slope was not different from 0) between number of systematically placed ($F = 2.12$; 1, 4 df; $P = 0.219$) or randomly placed ($F = 3.66$; 1, 4 df; $P = 0.128$) "artificial" prairie dogs detected by visual counts and vegetation density estimated with a Robel pole. Vegetation on all study colonies was uniformly short; mean Robel readings varied from 3.0 to 8.9 cm over all colonies in 1993 and from 3.0 to 6.9 in 1994. Few readings exceeded the obstruction point of 20.3 cm. Using the Menkens et al. (1990) method of correcting visual counts, 3 colonies would be increased by 1, 2, and 9 prairie dogs in 1993 and 1 colony by 4 animals in 1994. In this study, corrections did not affect correlation results. For example, using corrected values for maximum visual counts in 1993, resulting r^2 was 47.6% and SE was 4.22, compared to respective values of 47.0 and 3.14% for uncorrected counts. As a result, we decided not to apply correction factors to visual count data. Similar results and conclusions were derived by Menkens et al. (1990).

Burrow counts

Aerial videography was immediately rejected as a viable method for estimating populations of prairie dogs. Test flights over 3 colonies in 1993 revealed that resolution of images was so coarse that corner markers of plots could not be discerned. Markers

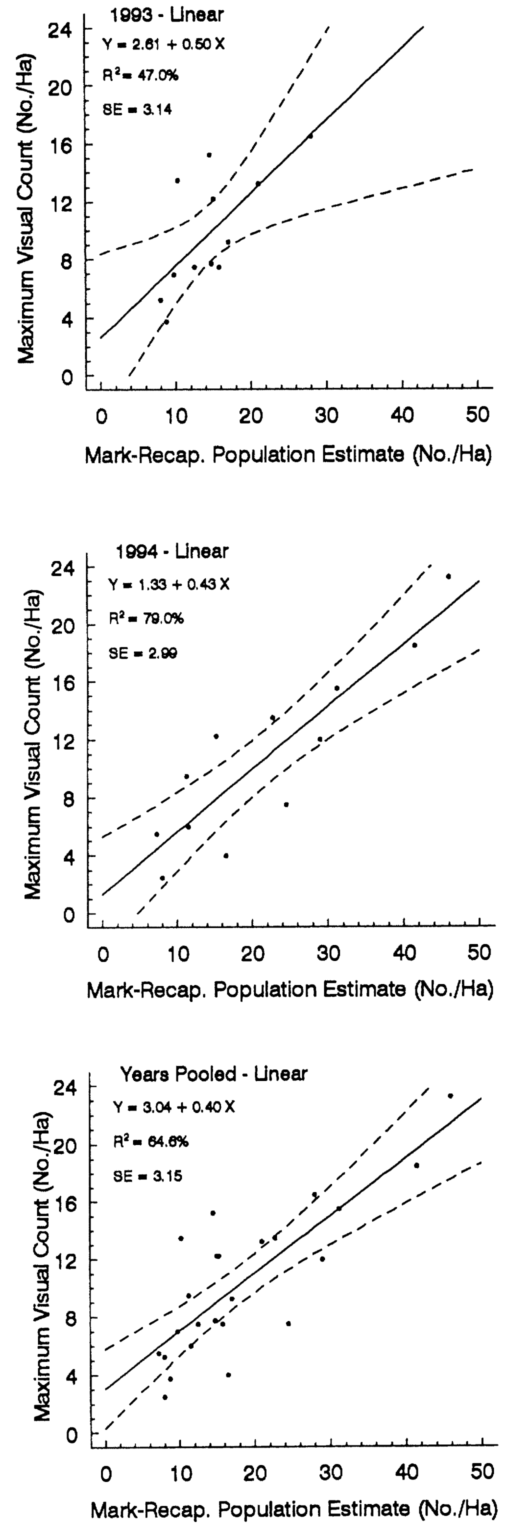

Fig. 1. Linear relationships, with 95% confidence limits on the mean between maximum visual counts (No./ha) of black-tailed prairie dogs and populations estimated by mark–recapture (No./ha) for 1993, 1994, and both years combined.

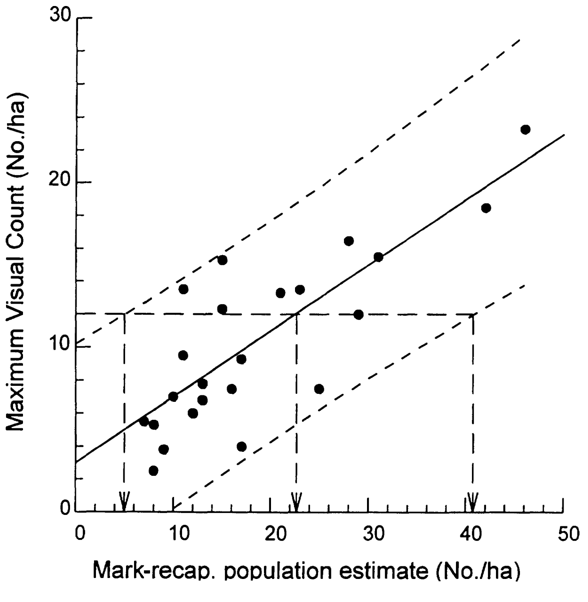

Fig. 2. Regression between maximum visual counts (No./ha) and mark–recapture population density (No./ha) with associated 95% prediction limits for a single observation. A calibration estimate of density (and associated 95% limits) given a visual count estimate is obtained by drawing a horizontal line from the visual count estimate through the regression model and prediction limits, then down to the density axis (e.g., for a visual count estimate of 12, the calibration density estimate is 22.4 with limits of 5.2 and 40.8).

were of a standard form used for aerial photography (Francis and Kerbs 1984) and were readily identifiable in the 1:4,000 color infrared photographs. We rejected the method at this point because, even if larger corner markers were used, resolution would not have been adequate to consistently identify burrows.

Little correlation occurred between mark-recapture population estimates and active or total burrow counts from ground transects or between population estimates and total mound counts from aerial photography. Slopes (b) were not different from 0 (Table 2). Examination of scatter plots did not reveal patterns attributable to old versus new colonies or hunted versus nonhunted colonies. Our findings confirm those suggested by Powell et al. (1994), but were in contrast to those of Biggins et al. (1993), who reported r^2 of 88.4% using active burrow counts on white-tailed prairie dog colonies and 42.5% on black-tailed colonies.

Management implications

Burrow counts, whether active-mounded, total active, total burrows (all from ground counts), or total mounds (from aerial photographs) should not be used to estimate or index prairie dog numbers. Absence of significant relationships between burrow counts and numbers estimated by mark-recapture methods over a 2-year period is evidence that the method is not reliable.

Active burrows, identified on the basis of presence or absence of prairie dog feces (see Biggins et al. 1993), are an indirect method of assessing populations and are subjected to bias induced by indirect forces. Localized, intense weather patterns can influence identification of active burrows. Significant precipitation events can cause feces to disintegrate or to be washed down the burrow. Also, prairie dogs landscape their mounds, especially after heavy rains (Hoogland 1995). Fecal material could be easily buried during such activities. Active burrow inventories done on different colonies at different times after such events could yield different relationships.

Visual counts, a direct form of assessing populations, have consistently yielded significant relationships with populations estimated via mark-recapture techniques (this study, Fagerstone and Biggins 1986, Menkens et al. 1990) and with populations determined by trapping all individuals within a colony (Knowles 1986). The best visual count estimator to use is the maximum count rather than the mean number counted (Knowles 1982, Fagerstone and Biggins 1986).

Although relationships between maximum visual counts and mark-recapture estimates are significant, a question remains—are the resultant models good enough to be used in a predictive sense; i.e., can they be used to compare populations among colonies, areas, and years? Menkens et al. (1990) suggested, and we concur, that visual counts could be used as an index to evaluate black-footed ferret reintroduction sites and to compare sizes of prairie dog populations between or among years. In this study, the inverse of the pooled mean model, $X = (Y-3.04)/(0.40)$, would be used to index black-tailed prairie dog densities under conditions similar to those encountered in this study. Such an estimate would not be very precise, however, as indicated by associated calibration limits (Fig. 2). Despite these limitations, the method is still better than any of the others we tested for monitoring prairie dog populations. At this point, only the more costly methods, such as mark-recapture or total trapping, would yield more precise data. Visual counts, though not difficult to obtain, should be made with a carefully designed protocol. Menkens and Anderson (1993) discussed the assumptions and factors to be considered when making visual counts of white-tailed prairie dogs. These are summarized below with some additions from the literature and some suggested changes (derived from this study) for black-tailed prairie dogs:

1. The plot must be of sufficient size to ensure a representative sample. Fagerstone and Biggins (1986) recommended that count plots be 10 ha and Menkens et al. (1990) recommended 8.1–13 ha for white-tailed prairie dogs. We used a smaller plot (4 ha) because black-tailed prairie dogs occurred at densities 2–5 times greater than white-tailed prairie dogs (See King 1955, Menkens et al. 1988, Menkens et al. 1990, and Powell et al. 1994). Also, burrow entrances were 2–6 times more abundant on black-tailed prairie dog colonies than on white-tailed prairie dog colonies (Stromberg 1978).
2. We did not address the number of 4-ha plots needed to ensure an adequate sample. Sample numbers would vary depending on distribution of animals within the sample area and the precision required. We suggest establishing a minimum of 3–5, 4-ha plots in a sample unit, counting prairie dogs as described below, then using these data to determine an estimate of plots needed using available formulations (e.g., Scheaffer et al. 1986).
3. Visual counts should be made from an elevated platform. We used a 4-legged, free-standing, commercially made deer stand, equipped with a canvas blind. Legs were cut down so the chair was 3 m above ground level.
4. Observers must be trained and equipped with

similar optical equipment. We had a 3-day training session in which all 4 observers practiced counting prairie dogs. All observers were equipped with similar optical equipment, binoculars (7 x 35mm).

5. Since maximum counts best reflect the population, we concur with the recommendation that counts be made at periods of peak activity (Fagerstone and Biggins 1986), both seasonally and daily. Population closure is assumed for the counting period. Therefore, counts should be made after young-of-the-year have emerged from the burrows and yearlings have dispersed, i.e., from mid-June to late August for black-tailed prairie dogs (Knowles 1982). Recreational shooting or any other activities that might influence the number or behavior of prairie dogs should also be eliminated during the count period.
6. The number of black-tailed prairie dogs above ground varies within days (Powell et al. 1994). Several counts should be made during each day and the same pattern of counting should be repeated over several days. Menkens et al. (1990) made 7 counts per day for 3 consecutive days. Fagerstone and Biggins (1986) made 3 counts per day, and we counted 4 times in each of 3 consecutive days. We concur with Menkens et al. (1993) that ≥3 counts be made each day over a 3-day period. Most count studies have centered on a morning period of 0700 to 1000 (Fagerstone and Biggins 1986, Menkens et al. 1990, this study) but the evening period would also suffice. Powell et al (1994) found black-tailed prairie dogs to be active during the evening period (2 hrs before sunset).
7. Counts corrected for visual obstructions did not improve correlations between maximum counts and mark-recapture population estimates either in this study or a study by Menkens et al. (1990). However, visual obstruction of sightings of prairie dogs may be a problem under some circumstances. Development of correction factors may be necessary; stratified sampling techniques may be required in other cases.
8. Weather conditions may affect counts. Although Powell et al. (1994) stated that weather effects on prairie dog activities were minimal, we noted that strong winds restricted aboveground activity. During 1 counting period, concurrent counts on 4 colonies ranged from 30 to 47 the first day, 24 to 50 the second, and 10 to 19 on the third. Temperatures were uniform (13-18°C), but wind speeds were 4, 28, and 44 km/hr, respectively, over the 3-day period. Menkens and Anderson (1993) suggested counting during moderate weather and we concur with this recommendation.

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