CHAPTER 6

Estimating the Abundance of Prairie Dogs

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Prairie dog populations have declined by about 98% over the last 200 years because of recreational shooting, poisoning, loss of habitat, and plague (Chapters 10, 11, 12, and 16). These numbers imply that we know how many prairie dogs existed 200 years ago, and how many remain today. In reality, however, accurate estimates of former and cnrrent numbers of prairie dogs are elusive.

One way to estimate numbers of prairie dogs is to count them. Counting prairie dogs is feasible only for small areas, however. For larger areas, an easier way to estimate the number of prairie dogs is to determine the area inhabited by them. When considering trends in the population size of prairie dogs within a particular state or across the former geographic range, biologists always focus on the cumulative area inhabited, from which they can (roughly) estimate the number of prairie dogs.

Early estimates of the abundance of prairie dogs are understandably nonrigorous and incomplete (e.g., the 1804 journals of Lewis and Clark, as reviewed by Burrougbs 1961 and Marsh 1984; see also Chapter 16). But recent estimates also reveal the difficulty of estimating abundance. An estimate in 2000 of 38,000 hectares (94,000 acres) inhabited by prairie dogs in Colorado, for example, ballooned to 255,000 hectares (630,000 acres) in 2004 after completion of new, more accurate surveys (Chapter 12). Similarly, an estimate in 2000 of 4,000 hectares (9,884 acres) inhabited by prairie dogs in Oklahoma swelled to 26,000 hectares (64,000 acres) in 2004 (Chapter 12). For its designation of the prairie dog as a candidate species for the Federal List of Endangered and Threatened Wildlife and Plants (FLETWP) in 2000, the United

States Fish and Wildlife Service (USFWS) calculated that prairie dogs inhabited 311,000 hectares (768,000 acres) throughout the entire geographic range (USFWS 2000a; Chapter 12). We now know, however, that prairie dogs inhabit somewhere between 0.5 and 0.8 million hectares (1.2–2.0 million acres) (USFWS 2004; Chapter 16). The larger estimates from 2004 for Colorado, Oklahoma, and the entire geographic range did not result because prairie dog populations proliferated from 2000 through 2004, but rather because the values from 2000 were serious underestimates.

Behavioral ecologists might need to count only the prairie dogs within a single colony to obtain information about demography and population dynamics (e.g., King 1955; Hoogland 1995). Similarly, wildlife managers might need to count only the prairie dogs within one or a few colonies on a national wildlife refuge to determine if grazing by domestic livestock is having a positive or negative impact. Governors, on the other hand, might want to know how many prairie dogs occur throughout their states, so that they can fairly evaluate the disparate claims and petitions of ranchers versus environmentalists. And USFWS officials wanted numbers throughout the entire former geographic range when they deliberated addition of the prairie dog to, and its later removal from, the list of candidate species for FLETWP (USFWS 2002a, 2004; Chapters 12 and 16). Objectives and scale for estimating the abundance of prairie dogs thus vary, and accuracy is always a priority. In this chapter we start by reviewing methods for determining the area inhabited by a colony of prairie dogs and then discuss ways to find and map colonies. We then explain different methods for estimating colony size and colony density.

Determining the Area Occupied by a Colony of Prairie Dogs

One common method to estimate the area occupied by a colony of prairie dogs involves forming a polygon by connecting the outermost burrow-entrances on a map of a colony-site (e.g., King 1955; Tileston and Lechleitner 1966; Hoogland 1995). Unfortunately, however, outermost entrances are difficult for wildlife managers to find, for two reasons. First, outermost entrances usually have small burrow-mounds, or no mounds at all; central entrances, by contrast, usually have large burrow-mounds called dome craters or rim craters (King 1955; Chapter 2). Second, outermost entrances typically are surrounded by tall vegetation (more than 30 centimeters [12 inches] high), whereas central entrances usually are in areas with low vegetation. Further, prairie dogs sometimes forage beyond outermost entrances (King 1955), so what do we really mean by area occupied? Despite these problems, outermost burrow-entrances yield a good estimate of area inhabited by prairie dogs.

The clip-zone is the central area of a colony-site where vegetation is low because of normal foraging, and also because prairie dogs sometimes clip vegetation without consumption—presumably to enhance detection of predators and conspecifics (King 1955; Hoogland 1995; Chapter 2). A second common method to determine the area inhabited by a colony is to map the clip-zone. Such mapping is easier said than done, however. The clip-zone is hard to detect in years of drought, for example, or when grazing by ungulates is especially heavy. Conversely, the clip-zone is also equivocal in years of copious precipitation, when the growth of vegetation outpaces foraging and clipping by prairie dogs. Further, the clip-zone varies with changing seasons and with the density of prairie dogs. Finally, prairie dogs commonly forage far outside the clip-zone (King 1955; Hoogland 1995).

Mainly because prairie dogs forage farther from the clip-zone than from outermost burrow-entrances, clip-zones are less accurate than outermost entrances for estimating a colony's area of occupancy. On the other hand, estimates of area from clip-zones are usually faster, less expensive, and more feasible from afar (e.g., from aircraft or satellites).

Finding and Mapping Prairie Dog Colony-Sites

To monitor the abundance of prairie dogs, biologists map the spatial location (i.e., latitude and longitude) and size of colony-sites. We then import these maps into a Geographic Information System (GIS), so that we can simultaneously view variables such as slope, predominant vegetation, altitude, and annual precipitation in relation to colony boundaries. Biologists commonly use three methods to find and map colony-sites: direct observations, aerial photography, and satellite imagery.

Direct Observations

One way to find prairie dog colonies is to look while walking or driving. Observers on foot or on all-terrain vehicles delineate boundaries of colony-sites by carrying Global Positioning System (GPS) receivers while searching for outermost burrow-entrances (Plumb et al. 2001). Though accurate, the combination of direct observations with GPS is slow, and therefore is only suitable for monitoring colonies within relatively small areas, such as Native American reservations, uational parks, and national wildlife refuges.

For larger areas (e.g., entire states), biologists sometimes use direct aerial observatious to map prairie dog colony-sites. Observers iu airplanes fly line-intercepts and record the flight path and length of lines flown above colonies

(Sidle 1999; Sidle et al. 2001), and then estimate the cumulative area of colonies from the percentage of the flight path intercepted by colony-sites.

Aerial Photography

Remote sensing provides information about the earth's surface from an overhead perspective (Campbell 1996). Methods of remote sensing include cameras mounted on airplanes (Table 6.1) and sensors attached to satellites. Dome craters and rim craters usually are visible in aerial photographs, and clip-zones are sometimes visible as well (Figure 6.1). Burrow-entrances in tall vegetation outside the clip-zone, or burrow-entrances without mounds, usually are not visible from aerial photographs.

Aerial photography is available at multiple scales, with resolution ranging from coarse (e.g., 1:250,000) to fine (e.g., 1:12,000). By varying the type of film and using different kinds of filters (e.g., haze-reducing), wildlife managers can obtain different types of information about prairie dog colony-sites.

Table 6.1. Use of conventional aerial photography to monitor prairie dog colonies.

Source	*Location*	*Type*	*Scale*
Cheatheam 1973	Texas	Black-and-white	1:7,920
Bishop and Culbertson 1976	North Dakota	Black-and-white	Various
Dalstead et al. 1981	South Dakota	Color, Color infrared, Black-and-white	1:15,840
Ernst 2001	Texas panhandle	Color, 35 mm	Ground resolution: 2 meters
Luse and Wilds 1992	Montana	SPOT	1:24,000
Nichols and Daley 1995	Colorado	Color, 35 mm (remote-controlled airplane)	1:4,200
Powell and Robel 1994	Kansas	Color, 35 mm	1:8,000 (enlarged)
Schenbeck and Myhre 1986	South Dakota	Black-and-white, Color infrared	1:16,000
Teitjen et al. 1978	South Dakota	Black-and-white	1:15,840
Uresk and Schenbeck 1987	South Dakota	Black-and-white, Color infrared	1:16,000
Vanderhoof and Robel 1994	Kansas	Color, 35 mm	1:8,000 (enlarged)

Figure 6.1. Aerial photograph of prairie dog colony-site near Lubbock, Texas. The light circles indicate burrow-mounds. Photo by Lubbock County Farm Service Agency.

Aerial photography is fast, inexpensive (sometimes less than $10 per photograph), and suitable for large areas such as entire states. Digital aerial photos provide high resolution and require neither film nor its processing. Computer hardware and software can enhance the utility of aerial photographs for mapping colony-sites. Further, archives of aerial photographs sometimes can provide a mechanism to track the inception, expansion, or demise of certain colonies. Aerial photography has several drawbacks, however. Bare soil and short vegetation away from colony-sites erroneously might indicate the presence of prairie dogs, for example, especially with images of low resolution. Further, delineation of small colony-sites (less than 5 hectares [12 acres]) is sometimes difficult from aerial photographs of low resolution. Perhaps the most important shortcoming is that aerial photographs usually cannot verify the presence of live prairie dogs, and therefore do not allow discrimination between active colony-sites versus colony-sites that recently have lost all prairie dogs (because of plague or poisoning, for example). Such verification requires direct observations from the ground (i.e., "ground-truthing") or from low-flying aircraft.

Satellite Imagery

For investigations across the prairie dog's cumulative geographic range of 160 million hectares (395 million acres) from Canada to Mexico, satellite imagery is more practical and consistent than aerial photography (Table 6.2). The low spatial resolution of traditional satellite systems such as Landsat (28.5-m resolution), Satellite pour l'Observation de la Terre (SPOT, 10-m), and Indian Remote Sensing (IRS, 5-m), however, has been only marginally successful for defining boundaries of colony-sites (Johnson et al. 2004). With one-meter resolution that clearly shows burrow-mounds within the clip-zone, Ikonos satellite imagery potentially solves the problem of defining boundaries (Sidle et al. 2002; Figure 6.2). At present, however, the cost of Ikonos is prohibitive for use throughout the geographic range of prairie dogs. Costs for similar results might decline if private companies launch satellites with one-meter resolution sensors that are independent of, and less expensive than, Ikonos. Like aerial photographs, satellite images cannot discriminate between active colony-sites versus recently deserted colony-sites.

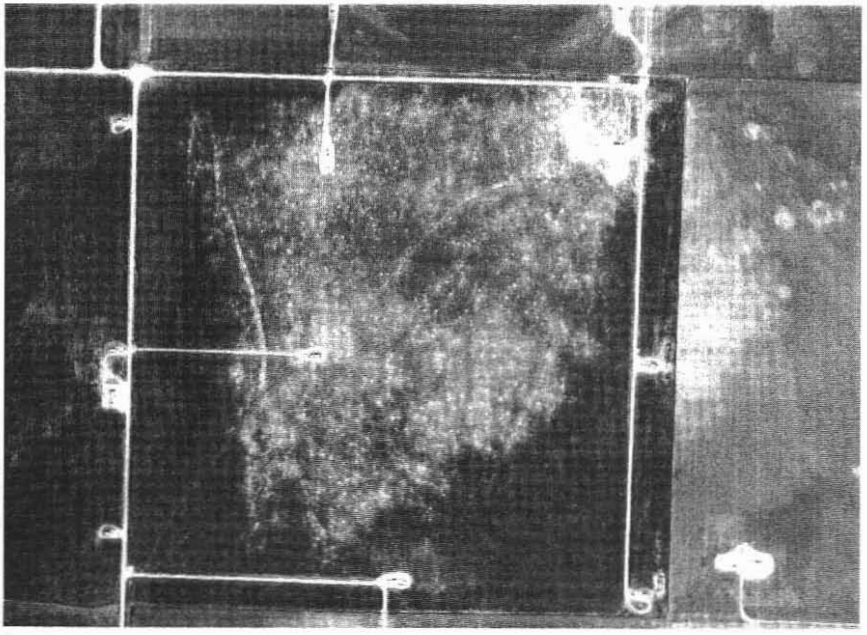

Figure 6.2. Ikonos satellite image of prairie dog colony-site. The light circles indicate burrow-mounds. Image by Space Imaging Incorporated.

Table 6.2. Advantages and disadvantages of several methods for estimating area inhabited by prairie dogs. Accuracy indicates how close our estimate is to the true value. Precision indicates variation among repeated estimates that use the same method.

Technique	*Precision*	*Accuracy*	*Cost*	*Processing time*	*Spatial resolution*	*Required equipment*	*Availability*	*Necessary training*	*Advantages*	*Disadvantages*
Global Positioning System (GPS)	High	High	High	Fast	High	GPS receiver	Not available, but easy to do	Little	High accuracy with good GPS receiver	Time-consuming; land accessibility might be difficult
Aerial transects	Low	Medium	High	Fast	Medium	Airplane, laptop computer, GPS receiver	Not available, but easy to do	Extensive	Coverage of large area	Time-consuming; high variation in data from different researchers
Aerial photography	Medium	Medium	Medium; low for archived imagery	Slow	High	Airplane, specialized software and tools	Available for parts of range only	Extensive	Low cost; high spatial resolution	Time-consuming; photographic quality and coverage both limited
Digital aerial photography	High	Medium	Low	Medium	High	Airplane	Available for entire range	Little	Low cost; high spatial resolution	Easy to lose digital data

Low-resolution satellite imagery	Medium	Low	Low	Slow	Low	Specialized Software	Available for entire range	Extensive	Low cost; extensive archives available	Low spatial resolution; detection of small colonies difficult
High-resolution satellite imagery	High	High	Currently high per image; might decrease over time	Slow	High	Specialized Software	Available for entire range	Little	Clearly defines colony-site boundaries; good for monitoring plots	High cost is prohibitive for entire range

Estimating Colony Size and Colony Density

Colony size is the number of prairie dogs that live in a colony. Biologists sometimes use the term for the number of adults and yearlings within a colony (Hoogland 1995; Chapter 2), but colony size for this chapter iucludes juveniles as well. Colony density is the number of adults, yearlings, and juveniles per hectare. The exact way to determine colony size and colony density is to mark all colony residents (King 1955; Hoogland 1995). Because catching and marking prairie dogs is so difficult and impractical, however, this method is reasonable for only a small number (less than about five) of small colonies (each with fewer than about 200 residents).

If colony density were constant, then accurate mapping of colony boundaries instantly would tell us colony size. But densities of prairie dogs vary over space and time with natural factors such as precipitation, vegetation, age of colony, and predation (King 1955; Hoogland 1995; Chapters 2 and 3), and with unnatural factors such as plague, recreatioual shooting, and poisoning (Chapters 8, 10, and 11). Methods for estimating colony size and colony density include visual counts, capture-mark-recapture (CMR), and inferences from number and density of burrow-entrances.

Visual Counts

Counting unmarked individuals is probably the most popular technique for estimating numbers of prairie dogs. With the aid of binoculars or a telescope, wildlife managers usually count prairie dogs from an elevated vantage point (with or without a blind) or from a parked vehicle (Figure 6.3). Jack Cully et al. used visual counts, for example, to document how plague ravaged prairie dog colonies at the Rocky Mountain Arsenal National Wildlife Refuge in the 1980s and 1990s (Chapter 11). The primary problem with visual counts is bias. Specifically, couuts are invariably lower than true colony size for two reasons. First, even though prairie dogs are diurual and spend many daylight hours aboveground, they frequently submerge for various reasons. Mothers commonly submerge into the home nursery burrow to nurse offspring, for example, or into another mother's nursery burrow for infanticide; males also submerge to kill jnveniles; both sexes suhmerge for mating; and both sexes also submerge to escape predators, human observers, excessive heat or cold, and precipitation (Hoogland 1995; Lehmer et al. 2001). Prairie dogs submerged for these reasons will be invisible during a visual count. Second, vegetation and burrow-mounds sometimes conceal prairie dogs that are aboveground, and poor lighting and certain background colors also impede the detection of prairie dogs by wildlife managers (Fagerstone and Biggins 1986; see also Menkens et al. 1990). Count-

Figure 6.3. Visual count. One way to estimate colony size is to count the number of visible prairie dogs. A visual count is always an underestimate because some prairie dogs are underground during the count, and because vegetation and burrow-mounds impede the detection of individuals. This visual count shows four individuals, but is that a fifth prairie dog—or a rock—on the burrow-mound in the distance? Photo by Kathy Boucher of Prairie Dog Specialists.

ing unmarked prairie dogs is easier than catching and marking, but nonetheless is suitable only for small- to medium-scale operations (less than about 100 colonies).

Estimates of the percentage of resident prairie dogs visible to human observers on a typical day range from 55% (Severson and Plumb 1998) to 57% (Biggins et al. 1993) to 86% (Knowles 1986b). Observers thus detect about two-thirds of the residents with each visual count.

Capture-Mark-Recapture (CMR)

Another way to estimate colony size involves capture-mark-recapture (CMR), for which precision varies directly with the number of prairie dogs that are

livetrapped. Prairie dogs violate the assumption of equal probability of capture, however, because certain individuals repeatedly enter livetraps, whereas others rarely enter (Hoogland 1995). Consequently, unless they can capture most or all residents within a colony, researchers must incorporate statistical techniques that accommodate unequal probability of capture (Otis et al. 1978; Fagerstone and Biggins 1986; Severson and Plumb 1998; see also Menkens and Anderson 1993). Methods for evaluating data from CMR are available in a program called MARK for personal computers (White and Burnham 1999).

Burrow-Entrances as Indicators of Prairie Dog Abundance

Wildlife biologists disagree about whether the number and density of burrow-entrances correlate with the number and density of prairie dogs. The conclusion of "no reliable index" (King 1955, p. 23) overstates the case, because presence of entrances demonstrates presence (past or current) of prairie dogs, and absence means absence of prairie dogs (Biggins et al. 1993). The following phenomena imply, however, that the correlation between colony size and the number of burrow-entrances must be highly variable (King 1955; Hoogland 1981a, 1995; Chapter 2):

- Individuals within a coterie enter and exit numerous burrow-entrances in a typical day. Further, several individuals of the same coterie commonly spend the night in the same entrance, or enter the same entrance during the day to escape from predators. Thus, each prairie dog does not have its own private burrow-entrance or set of entrances.
- A single burrow commonly has two or more entrances.
- The number of prairie dogs within a colony fluctuates seasonally and annually, but the number of burrow-entrances for that colony remains remarkably stable. At John Hoogland's (1995) study-colony at Wind Cave National Park, for example, the number of adults, yearlings, and juveniles ranged from 92 to 250 over 15 years, but the number of burrow-entrances over the same 15 years was always almost exactly 1,600.

Regarding the inference of colony size from the number of burrow-entrances, critics (Powell et al. 1994; Severson and Plumb 1998) and supporters (Biggins et al.1993; Johnson and Collinge 2004) understandably interpret the utility of the inference relative to their own data and objectives. An inference that Jack King (1955) considered unreliable for his research might satisfy requirements for other research. Similarly, John Hoogland concluded (1995, page 36) that ". . . neither the number nor density of burrow-entrances accurately predicts prairie dog colony size . . . or colony density." But might an

"inaccurate" prediction be suitable for other purposes? The debate regarding burrow-entrances versus colony size probably should refocus on whether the correlation is high enough for the specific problem under investigation.

For small-scale research, mapping burrow-entrances within all or part of a single colony-site might be possible (e.g., King 1955; Hoogland 1995). For larger-scale research, one way to estimate the number of entrances at a colony-site is to use strip transects (Biggins et al. 1993). Counting only "active" burrow-entrances might increase the accuracy of estimating colony size from the number of burrow-entrances; Biggins et al. (1993) defined an "active" entrance as one with fresh scat (i.e., fecal pellet that is greenish, black, or dark brown rather than bleached) on the burrow-mound or less than one meter away. Counts of active entrances correlated with the decline of white-tailed prairie dogs at Meeteetse, Wyoming, over ten years (Figure 6.4; see also Biggins and Kosoy 2001a). From colonies with good estimates of colony size from visual counts of residents (adults, yearlings, and juveniles), the average number of active burrow-entrances per black-tailed prairie dog is 3.9 (N = 39

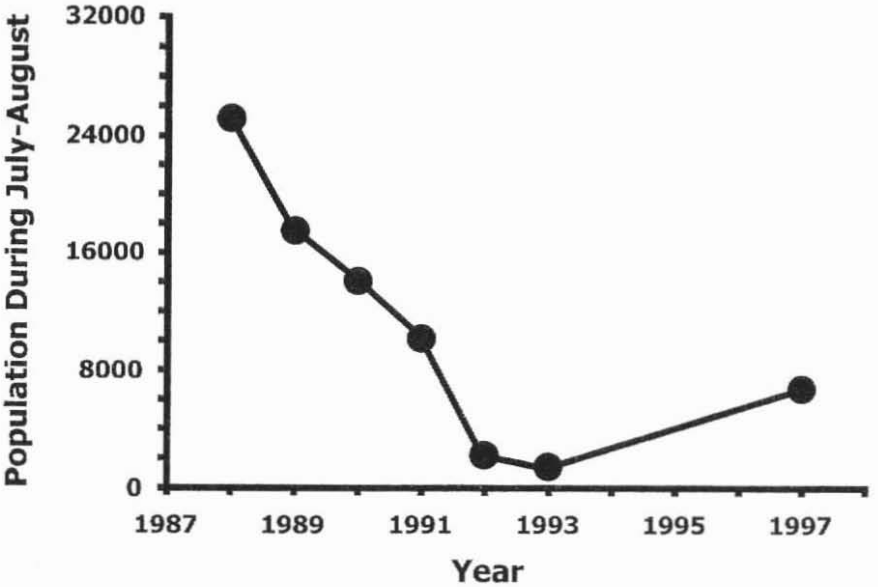

Figure 6.4. The number of adult and juvenile white-tailed prairie dogs in the vicinity of Meeteetse, Wyoming, estimated from strip transect surveys of active burrow-entrances in July and August (from Biggins and Kosoy 2001a). The population, which originally contained several colonies, crashed because of plague. The average number of active burrow-entrances per white-tailed prairie dog is 11.5.

colonies); the average number of active burrow-entrances per white-tailed prairie dog is 11.5 (N = 30 colonies) (Biggins et al. 1993).

Scale evidently affects the ability to detect relationships between densities of prairie dogs and densities of burrow-entrances. We use the term "scale" here to indicate the number of sampled colony-sites and their geographic range, and the ranges of densities for prairie dogs and burrow-entrances. In a large-scale study of 22 colonies in Colorado, density of prairie dogs (estimated from visual counts of adults, yearlings, and juveniles) correlated positively with densities of active burrow-entrances (range of prairie dogs per hectare = 32–120 [13–49 per acre] and range of active entrances per hectare = 100–674 [40–273 per acre]) (Johnson and Collinge 2004). A similar positive correlation was evident in another large-scale study of 39 colonies sampled over a three-state region (range of prairie dogs per hectare = 0.8–54.2 [0.3–21.9 per acre] and range of active entrances per hectare = 0.4–156.4 [0.2–63.3 per acre]) (Biggins et al. 1993). On smaller scales, densities of prairie dogs and burrow-entrances did not significantly correlate in either South Dakota (12 colonies; range of prairie dogs per hectare = 8–41 [3–17 per acre]; Severson and Plumb 1998) or Kansas (5 colonies; range of prairie dogs per hectare = 29–79 [12–32 per acre]; densities of active entrances rated as low, medium, or high; Powell et al. 1994).

The stability of the number of burrow-entrances over time, a disadvantage for tracking short-term changes in colony size (King 1955; Powell et al. 1994; Severson and Plumb 1998), can be an advantage for attempts to evaluate the suitability of habitat. The number of prairie dogs that inhabited (or might inhabit) a colony-site ravaged by plague, for example, sometimes can be estimated from the total number of burrow-entrances—because entrances are sometimes recognizable for as long as five years after prairie dogs have disappeared.

Which method should a conservation biologist, wildlife manager, or environmentalist use to estimate the abundance of prairie dogs? The answer will depend on the size of area under investigation, objectives, budgetary constraints, available equipment, and the necessary level of accuracy.

Summary

- One common method to estimate the area occupied by a colony of prairie dogs involves forming a polygon by connecting the outermost burrow-entrances on a map of a colony-site. A second common method is to map the clip-zone (the central area of a colony-site where vegetation is low because of foraging and clipping).
- To find and map prairie dog colonies, biologists rely on direct observations, aerial photography, and satellite imagery. Direct observations are adequate

for finding and mapping colonies within small areas such as national parks and national wildlife refuges. For larger areas such as entire states or groups of states, observations and photographs from airplanes are appropriate.

- For estimating the area inhabited by prairie dogs throughout their entire geographic range, satellite imagery is more practical than aerial photography. With one-meter resolution that clearly shows burrow-mounds, Ikonos satellite images of colony-sites are excellent. The current cost of Ikonos, however, is exorbitant. Cheaper, similar results might soon be available if private companies launch satellites with one-meter resolution sensors.
- If density of prairie dogs were constant, then mapping boundaries of a colony-site would accurately indicate the number of prairie dogs living there. But densities of prairie dogs vary over space and time with natural factors such as precipitation, vegetation, age of colony, and predation, and with unnatural factors such as plague, recreational shooting, and poisoning.
- The most accurate method for estimating colony size and colony density is to capture all the prairie dogs and mark them. Because this method is so difficult, however, catching and marking is reasonable for only a small number (less than about five) of small colonies (each with fewer than about 200 residents). When wildlife managers can capture some but not all colony residents, we can use various statistical techniques to estimate colony size.
- The second most accurate method for estimating colony size and colony density is to count unmarked prairie dogs. These counts usually indicate only about two-thirds of the resident prairie dogs, however, because some individuals are usually underground for various reasons and because all aboveground individuals are not visible. Counting unmarked prairie dogs is easier than catching and marking, but nonetheless is suitable only for small- to medium-scale operations (less than about 100 colonies).
- Numbers and densities of prairie dogs roughly correlate with numbers and densities of active burrow-entrances, and these correlations are better for large-scale operations (i.e., numerous large colonies spread over several counties, with hefty variation in densities of both prairie dogs and burrow-entrances) than for smaller-scale operations.
- The most appropriate method for estimating numbers of prairie dogs will depend on size of area under investigation, objectives, budgetary constraints, available equipment, and the necessary level of accuracy.

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Saving North America's Western Grasslands

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