EVALUATION OF BARRIERS TO BLACK-TAILED PRAIRIE DOG (*Cynomys ludovicianus*) COLONY EXPANSION, BAD RIVER RANCHES, SOUTH DAKOTA

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the 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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Abstract

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The state of South Dakota recently approved a black-tailed prairie dog (*Cynomys ludovicianus*) conservation and management plan (House Bill 1252 and Senate Bill 216, An Act to Mitigate the Impact of Prairie Dogs), which placed restrictions on prairie dog colonies that encroach upon private property where their presence was not desired. A one-mile (1.6 km) prairie dog free zone must be maintained if a formal complaint was issued with the state. Passage of the plan elevated the importance of barrier development in the management of prairie dogs. The objectives of our study were: (1) evaluate the efficacy of different physical and visual barrier designs at limiting the expansion of prairie dog colonies and (2) analyze the cost-effectiveness of barrier designs in terms of materials, installation, and maintenance. Five study sites were chosen on the Bad River Ranches owned by Turner Enterprises, Inc. in Stanley and Jones counties near Fort Pierre, South Dakota. Barriers evaluated included: vinyl sheeting with chicken wire, American bison (*Bison bison*) exclosures, and straw bales. Barriers were 100 meters (328 ft) in length and located within 1 hectare monitoring plots (2.47 ac). Grazing and mechanical mowing were allowed on both sides of barriers. A prairie dog free zone was established on property adjacent to active colonies. Variables such as weather, soil type, topography, vegetative characteristics, prairie dog density, and rate of expansion were recorded for each colony. Efficacy of barriers was evaluated by the presence of active burrows in the prairie dog free zone beyond barriers (breakthroughs) and the relative cost of each barrier type. We documented 528 active burrows beyond treatments, 231 occurred within the control (where no barrier was established). The exclosures, vinyl, and straw bales exhibited 122, 78, and 97 burrows respectively. There was a significant difference (P = 0.018) among the constructed barrier treatments and the control in terms of limiting the number of prairie dog breakthroughs. The cost of vinyl sheeting and chicken wire was $898.68 per 100 m (328 feet). The cost associated with bison exclosures was $341.93 per 100 m (328 feet). While both barrier treatments significantly reduced prairie dog recolonization, the bison exclosure cost substantially less than the vinyl sheeting and chicken wire. The vinyl sheeting and chicken wire required more ($P \leq$ 0.10) maintenance than the bison exclosure. We compared two methods of prairie dog density estimation, mark-recapture and mark-resight. Our estimates of prairie dog density (25.60 – 36.43 prairie dogs per hectare [~ 10 – 15 per acre]) were within the range reported in published studies for the species using mark-recapture or mark-resight approaches. There was no significant difference (P = 0.796) between our estimates of prairie dog density among methods or years. Use of barriers to deter movement of prairie dogs may represent a viable alternative to poisoning. Information that must be considered when selecting a prairie dog barrier includes maintenance time involved for the treatment to remain effective. It is the responsibility of the manager to decide which control method

or combination of methods (lethal and non-lethal) to employ on a given site at a given time to successfully balance the needs of stakeholders while maintaining prairie dogs on the landscape.

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Chapter 1

General Introduction

Status

On 2 December 2008, the United States Fish and Wildlife Service (USFWS) issued a decision in a 90-day petition finding that reported "substantial evidence" that the status of the black-tailed prairie dog (*Cynomys ludovicianus)* warranted additional investigation (United States Fish and Wildlife Service 2008). The report was the preliminary step in the process to designate the species as a candidate for listing under the Endangered Species Act (ESA) of 1973. Upon further review, the USFWS is anticipated to release a new 12-month petition finding in which the agency will provide recommendations for the prairie dog population that may include listing the species as threatened or endangered under the ESA.

The 2008 finding was not the first time the USFWS reviewed the status of the black-tailed prairie dog. In 1998, the USFWS received two petitions to list the prairie dog as threatened throughout its range. In 1999, the review process demonstrated that again, the 90-day petition finding was substantial (United States Fish and Wildlife Service 1999). However, upon the release of the initial 12-month petition finding in 2000, the status of prairie dogs was determined to be "warranted but precluded" by species of more urgent conservation priority (United States Fish and Wildlife Service 2000[a]). The impetus for the most recent petitions to review the status of prairie dogs was the fact that many of the threats to the population have not been appropriately or sufficiently addressed by states where the species is found, despite the efforts of the affected states to develop adequate management plans (Cooper and Gabriel 2005) in accordance to guidelines established by the USFWS (United States Fish and Wildlife Service 2000[b]). The intent of management plans was to reduce or remove the threats to the prairie dog population and to maintain the management authority of the species with the states rather than the federal government. Four major impacts to the prairie dog population have been identified and include: loss and destruction of habitat, large scale control projects that reduce or eliminate prairie dogs, susceptibility of the species to sylvatic plague (*Yersinia pestis*), and lack of regulatory mechanisms to protect prairie dogs from overexploitation (United States Fish and Wildlife Service 2000[a]).

Conversion of prairie dog habitat in the eastern portion of the geographic range of the species to agricultural uses has occurred since the 1880's. Prairie dog habitat loss and destruction was originally limited by precipitation patterns and crop resiliency. However, in recent decades drought-resistant varieties of row crops have been developed and continue to expand native grassland conversion farther west (United States Fish and Wildlife Service 2000[a]). Furthermore, improved dry-land farming techniques have made cultivation profitable in areas that were not historically planted (United States Fish and Wildlife Service 2000[a]). Recent developments that threaten to increase the rate of agricultural expansion across the range of the black-tailed prairie dog include high commodity crop prices coupled with uncertainty as to the continuation of the Conservation Reserve Program (CRP) and other landowner incentives contained within the Farm Bill (Janssen 2009).

Due to competition with livestock, real or perceived, vast expanses of prairie dog colonies were eradicated by governmental control projects across state, federal, tribal, and private land (United States Fish and Wildlife Service 2000[a]). While activities of prairie dogs cause economic impacts in certain situations (i.e., crop depredation), the detrimental influence of the species on native rangeland is inflated (Hoogland 1995). Control of prairie dogs conducted on rangeland in South Dakota, and other states, originally used strychnine treated oat bait (Hanson 1988). Currently, control agents lawful for application in South Dakota include: zinc phosphide treated oat bait, aluminum phosphide fumigant, and carbon dioxide (CO_2) gas cartridge (South Dakota Department of Agriculture 2007). In 2007, the South Dakota Department of Game, Fish, and Parks reported that total prairie dog colony poisoning in 2006 (as part of the State Animal Damage Control program) was approximately 17,000 hectares (42,000 acres) (Kempema 2007).

The first recorded outbreak of sylvatic plague in South Dakota occurred in 2004 (South Dakota Department of Game, Fish, and Parks 2004), with the documented expansion of the disease in 2005. Sylvatic plague is caused by the transfer of the bacterium *Yersinia pestis* from infected fleas. Black-tailed prairie dogs are highly susceptible to plague epizootics and experience nearly 100% mortality (Cully 1993). During summer 2008, an outbreak of sylvatic plague occurred in southwestern South Dakota, which affected the Conata Basin area of the Buffalo Gap National Grassland. This area, famous for the reintroduced population of black-footed ferrets (*Mustela nigripes*), experienced a loss of approximately 3,640 hectares (9,000 acres) of prairie dog colonies by late June despite timely application of pesticides to control flea populations by a coalition of personnel from various agencies (United States Geologic Survey 2008). Eastward expansion of sylvatic plague raises concerns with regard to the stability of prairie dog populations when confronted with a combination of factors influencing the continuation of the species on the landscape (United States Fish and Wildlife Service 2000[a]).

Lack of regulatory mechanisms to protect prairie dogs from overexploitation also has contributed to the candidate status of the species (United States Fish and Wildlife Service 2000[a]). Recreational shooting of prairie dogs is a popular pastime. The practice can be lucrative to landowners who want to reduce prairie dog numbers on their property because an increasing proportion of shooters are willing to pay for access to prairie dog colonies (Tom LeFaive, Ranch Manager – Bad River Ranches, pers. comm.). There are no bag limits and a continuous open season (varmint status) for prairie dogs in many areas across their range (United States Fish and Wildlife Service 2000[a] and United States Fish and Wildlife Service 2008). As a designated pest, the presence of prairie dogs is considered an infestation requiring removal. South Dakota now requires that prairie dog shooters possess a valid hunting license to shoot prairie dogs and have closed the season from 1 March through 14 June on public land. The exception to this change in season is that no prairie dog shooting can occur on the Conata Basin Area of the Buffalo Gap National Grassland. Prairie dogs can be shot year-round on private land in South Dakota (South Dakota Department of Game, Fish and Parks 2009).

Natural History

Black-tailed prairie dogs (*Cynomys ludovicianus*) are semi-fossorial (Franklin and Garrett 1989) members of the family *Sciuridae.* They measure 355 – 415 mm (14-16 3/8 in) and weigh 900 – 1,360 g (32 – 48 oz) (Whitaker 1997). Four additional species of prairie dogs are found in North America; white-tailed (*Cynomys leucurus*), Utah (*Cynomys parvidens*), Gunnison's (*Cynomys gunnisoni*), and Mexican (*Cynomys mexicanus*). Of the five species of prairie dogs, the black-tailed is the most numerous, has the largest geographic distribution, and is the most colonial (Hoogland 1995). The black-tailed prairie dog can be found from southern Canada to northern Mexico and east of the Rocky Mountains to the mixed-grass prairies of North and South Dakota, Nebraska, Kansas, Oklahoma, and Texas (Hoogland 1995). The black-tailed prairie dog is the only species found in South Dakota. As of 2006, prairie dog colonies encompassed approximately 473,500 hectares (1,170,000 acres). The total land area of South Dakota counties within the geographic range of prairie dogs is approximately 15,200,000 hectares (37,600,000 acres) located primarily in the western two-thirds of the state and characterized by mixed and short-grass prairies (Kempema 2007). However, not all of the potential acreage available in South Dakota constitutes suitable prairie dog habitat due to topographic, vegetative, and soil characteristics that limit successful colonization by the species.

Prairie dogs live in geographically defined groups known as colonies or towns (King 1955). Colonies are further subdivided into wards that are often separated by unsuitable habitat. Prairie dogs are polygynous and form territorial family groups termed coteries where members are defended from non-members via scent. Coteries are generally comprised of one breeding male, two to three adult females, and one or two yearlings of each sex. Female prairie dogs tend to remain in their natal coterie, while juvenile males will disperse as yearlings to other areas once the current year's offspring are born. To escape predation and avoid weather extremes, prairie dogs excavate and occupy burrows characterized by a length of several meters and multiple entrances. Predation risk is further reduced by the sentinel behavior exhibited by prairie dogs where sophisticated vocal alarm calls alert other individuals to the presence of a predator (Hoogland 1995).

Male and female prairie dogs typically reach sexual maturity at two years of age. One litter of pups is born in the spring; mean litter size is 3. Infanticide has been documented by dominant females prior to emergence of litters within a coterie and can account for nearly 40% of juvenile mortality. Once the pups emerge from underground, females communally rear the young, which results in observations of large numbers of pups on a single burrow. Male prairie dogs live for up to five years and females up to eight years of age. The first-year mortality (50%) is similar for both sexes (Hoogland 1995).

Prairie dogs maintain short vegetation by actively clipping plants within the colony. Clipping behavior enhances predator detection by improving visibility for individuals scanning for predators, as obstructions are removed. Short vegetation maintenance by prairie dogs within colonies is viewed as degrading forage availability to livestock where prairie dogs and livestock are sympatric (Hoogland 1995). There is evidence that clipping behavior by prairie dogs actually improves forage quality of certain plants by maintaining vegetation in an active growth stage, which is more nutritious and palatable to grazing animals (Hoogland 1995). Vermeire et al. (2004) identified how research on the influence of prairie dogs on the landscape has disparate results depending on whether the organization conducting the investigation was in favor of prairie dog restoration or considered the species a pest. Studies also have suggested that barriers to colony expansion (native vegetation and constructed) may be effective in reducing colonization rates of prairie dogs (Franklin and Garrett 1989 and Terrall 2006).

Literature Review

The black-tailed prairie dog (*Cynomys ludovicianus*) has traditionally been controlled using lethal techniques, such as shooting and poisoning (Knowles 1986, Klukas 1987 and Merriman et al. 2004). However, the use of non-lethal approaches to limit prairie dog colony expansion has been investigated since the 1980's (Franklin and Garrett 1989). Non-lethal methods of colony management include translocation as well as the establishment of visual and physical barriers to colony expansion (Merriman et al. 2004). These approaches are the result of changing attitudes toward the functions that prairie dogs perform in ecosystems, such as influencing vegetative composition, serving as prey to a wide range of species (i.e., American badger [*Taxidea taxus*], bobcat [*Lynx rufus*], coyote [*Canis latrans*], swift fox [*Vulpes velox*], ferruginous hawk [*Buteo regalis*], rattlesnake [*Crotalus spp*.]), as well as providing nesting or den sites for species, such as the burrowing owl (*Athene cunicularia*) and the federally endangered black-footed ferret (*Mustela nigripes*) (Sharps and Uresk 1990, Wuerthner 1997, and Lomolino and Smith 2003).

Researchers have investigated a wide array of methods and techniques in an attempt to identify an effective barrier to prairie dog colony expansion that can be used on a broad scale. Artificial and natural materials have been incorporated into barrier designs with mixed results. Franklin and Garret (1989) experimented with cut ponderosa pine (*Pinus ponderosa*) trees and successive rows of burlap material (1-m high) in Wind Cave National Park, South Dakota. They found that artificial barriers (burlap) reduced the rate of prairie dog colony expansion with an expansion rate of 8% for the treated areas and 54% for control areas. Furthermore, the cut pine treated areas successfully limited prairie dog colony expansion, likely due to the visual and physical influence on the movements of individuals. However, Hyngstrom (1996) concluded that plastic snow fencing was ineffective at limiting prairie dog colony expansion. The ability of prairie dogs to see through the barriers due to materials and construction techniques as well as the vulnerability of barriers to damage caused by environmental factors are reasons cited for the potential inadequacy of artificial barriers. Recommendations of Hyngstrom (1996) such as securing solid barrier materials in trenches, made it possible for future experiments to incorporate barrier materials and installation methods that address the limitations of constructed barriers to prairie dog colony growth. In New Mexico, Merriman et al. (2004) indicated that galvanized roofing material and commercial silt fence failed to prevent prairie dog expansion. According to Foster-McDonald et al. (2006) prairie dogs did not respond to visual barriers as expected and actually, “did not increase the frequency of vigilant or aggressive behavior, the size of use areas, or the distance of their use areas from the visual barriers." Other techniques such as attempting to increase the mortality rate of prairie dogs by attracting predators to colonies by installing raptor perches and predator ambush cover have had minimal impact on reducing overall colony expansion (Snell and Hlavachick 1980 and Knowles 1982).

Terrall (2006) used natural vegetative buffer strips of varying widths as barriers to prairie dog colony expansion. Much of the previous work in controlling prairie dog populations with natural vegetation focused on manipulating the grazing pressure of prairie dog colonies by livestock. Deferred grazing by cattle or reduced stocking rates released natural vegetation to grow, which would reduce the ability of prairie dogs to monitor for predators and thus increase their mortality (Cable and Timm 1988). Terrall (2006) conducted a field experiment in which cattle were excluded from grazing buffer strips of natural vegetation (10, 25, and 40 m in width and 100 m in length). Terrall (2006) compared the buffer strips to areas where no barrier was established as experimental controls and developed a predictive model for the movement of prairie dogs through barriers in relation to vegetation height and buffer width: Breakthrough=exp (2.410-0.004*Veg Height-0.036*Buffer Width). In this model, a "breakthrough" was defined as an active prairie dog burrow beyond a barrier. Using his model, Terrall (2006) identified that an optimum buffer width of 100 m (328 feet) was required to successfully limit prairie dog colony expansion given the estimated mean vegetative height of 40 cm (15.7 in) in western South Dakota. Furthermore the visual obstruction reading (VOR), or density of vegetation, was highly correlated ($r^2 = 0.86$) with vegetation height (Terrall 2006).

Objectives

The objectives of this study were to evaluate the efficacy of physical and visual barriers to colony expansion as well as to compare the cost-effectiveness of different barrier design types in terms of materials, installation, and maintenance. In our investigation, we evaluated artificial as well as natural vegetative barriers to prairie dog colony expansion. Using an experimental framework consisting of multiple treatments applied across multiple replicates, we provide a more robust experimental investigation into the issue of barriers to prairie dog colony expansion. Some of the previous work regarding prairie dog barriers was conducted on only one or two colonies with a limited number of treatments that may or may not have been replicated.

We estimated prairie dog density within monitoring plots adjacent to barriers to investigate the potential effect of prairie dog density on barrier breakthroughs. We compared two methods of prairie dog density estimation, mark-recapture and mark-resight techniques (Severson and Plumb 1998). There has been considerable disagreement in the literature concerning the most appropriate technique to estimate prairie dog density (Magle et al. 2007 and Facka et al. 2008). Agencies that manage prairie dogs have disparate methods of estimating density and occupancy rates of the species across its range (Magle et al. 2007 and Facka et al. 2008). Techniques employed include: burrow counts, mark-recapture, and visual counts. Burrow counts are either conducted as an aerial or ground survey and use a ratio of active to inactive burrows as a surrogate for the actual number of individuals for a given area. While the relationship among burrow counts and prairie dog density has been shown to be invalid (Severson and Plumb 1998), the technique continues to be practiced (Fagerstone et al 2005, Gershman et al 2005, and Bly 2006). Our objective was to evaluate the last two methods of prairie dog density estimation; mark-recapture and visual counts. The visual counts we conducted are more appropriately termed mark-resight estimates, due to the trapping and marking of individuals involved. Rather than simply counting the number of individual prairie dogs observed, we were able to use the observations of marked individuals as a surrogate for successive physical capture events. The ratio of marked to unmarked individuals observed within a monitoring plot during a given survey period was used to estimate prairie dog density comparable to traditional mark-recapture methods. Mark-recapture and mark-resight estimates may serve as appropriate and comparable methods to estimate density of black-tailed prairie dogs.

Knowledge gained in this investigation will supplement existing non-lethal methods of prairie dog management and further our understanding of obtaining reliable estimates of prairie dog density to effectively monitor the population dynamics of the species. With this information we may increase our ability to effectively manage the species in terms of striking a balance between the requirements of people and prairie dogs.

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Chapter 2

Evaluation of two methods of black-tailed prairie dog (*Cynomys ludovicianus*) density estimation

Introduction

Considerable disagreement exists in the literature concerning the most appropriate technique to estimate black-tailed prairie dog (*Cynomys ludovicianus*) density (Magle et al. 2007 and Facka et al. 2008). Agencies that manage prairie dogs have disparate modes of estimating density and occupancy rates of the species across its range. Techniques employed include: burrow counts, mark-recapture, and visual counts. Burrow counts are either conducted as an aerial or ground survey and use a ratio of active to inactive burrows as a surrogate for the true number of individuals for a designated area. While the relationship among burrow counts and prairie dog density has been shown to be invalid (Severson and Plumb 1998), the technique continues to be employed (Fagerstone et al. 2005, Gershman et al. 2005, and Bly 2006). The purpose of this study was to evaluate two methods of prairie dog density estimation; mark-recapture and visual counts.

Study Area

Research was conducted on Bad River Ranches [N44°16.1’ W100°32.0’, ~352 km^2 (~220 mi^2), ~560 m (~1830 ft.)] owned by Turner Enterprises, Inc. in Stanley and Jones counties near Fort Pierre, South Dakota. Topography consisted of flat to rolling uplands cut by the Bad River and intermittent drainages. Soils were primarily clays derived from Cretaceous Pierre Shale (Johnson et al. 1995). The area was characterized as a wheatgrass-needlegrass (*Stipa viridula*) community within the mixed-grass system of the Northern Great Plains (Kuchler 1975). Buffalo grass and blue grama grass also were widespread (Bly and Truett, unpublished data). The ranches were managed for the sustainable production of American bison (*Bison bison*) and conservation of native species.

Methods

In 2006, we identified 5 prairie dog colonies as experimental replicates for use in the estimating density of prairie dogs for 2007 and 2008. Within each study colony, we randomly delineated 3 monitoring plots, each 1 ha (2.47 ac) in size. During 2008, 3 of the 5 colonies had an additional monitoring plot. A 5 x 10 trap grid was established using a total of 50 live-traps per monitoring plot. Traps were 48 cm x 15 cm x 15 cm (19 in x 6 in x 6 in) with a single door (Model 103, Tomahawk Live Trap, Tomahawk, Wisconsin). We pre-baited with commercial horse sweet feed (corn, oats, wheat, barley, alfalpha pellets, and molasses) (Nutrena Feeds, Giddings, Texas) for 3 days prior to commencement of trapping to habituate prairie dogs to presence of cage traps. Trapping sessions were 3-5 days per colony and varied based on the ratio of new individuals to recaptures. A buffer zone of 20 m (65 feet) was used to ensure independence of the trap grids. Visually dissimilar marking patterns were applied (non-toxic fur dye [RIT Dye, Phoenix Brands, LLC., Stamford, Connecticut]) to prairie dogs in each monitoring plot, respectively, to allow for capture location identification and thus, facilitate population closure. We constructed a denim handling-sleeve of similar design to Hoogland (1995) for handling prairie dogs. We followed the animal care and use guidelines as outlined by the American Society of Mammalogists (American Society of Mammalogists 2007) and the Animal Behavior Society (Animal Behavior Society 1986). Our capture protocol was approved (Approval No. 07-A006) by the Institutional Animal Care and Use Committee at South Dakota State University.

Visual counts that we conducted were more appropriately termed mark-resight estimates. The technique was similar to traditional mark-recapture estimates; however, rather than physically recapturing an individual prairie dog, a visual observation was used in lieu of successive capture events. We followed recommendations of Severson and Plumb (1998) for estimating prairie dog abundance. Visual counts were conducted within the monitoring plots 3 times per day for 3 days post trapping and marking. Counts were 15-30 minutes apart and conducted with a spotting scope from a vehicle. Prairie dog counts were conducted during times of daily peak activity (0700 – 1030 or 1800-2130 or longer) within the optimal seasonal time period of mid-June to late August. No counts were conducted during inclement weather (rain, high wind, or high temperatures). To reduce observer bias, only one observer conducted visual counts. The observer arrived at least 30 minutes prior to the census period to minimize the effects of human disturbance.

We analyzed the mark-resight data for each monitoring plot by multiplying the known number of marked prairie dogs by the total number of prairie dogs observed (marked and unmarked) and then divided by the number of marked prairie dogs observed. To reduce the potential bias in our estimate, we used the Corrected Lincoln-Petersen Index (n+1) (Lancia et al. 1996). Once we determined the mean prairie dog density per monitoring plot, we calculated the mean prairie dog density per study colony by summing the estimates and dividing by the number of monitoring plots on each site. The procedure to estimate prairie dog density by mark-recapture technique was the same as that for mark-resight estimates. To compare mean prairie dog density relative to method, we conducted two-sample t-tests.

Results

In total, we captured and processed 800 individual prairie dogs during this investigation. From our mark-recapture and mark-resight data, we calculated an estimate of prairie dog density on each of the 5 study colonies sampled during 2007 and 2008 (Table 2.1) based on the ratio of marked to unmarked individuals in our samples (King 1955 and Lancia et al. 1996). Mean prairie dog density across all colonies based on the mark-recapture technique was 29.59 prairie dogs per hectare (~12 per acre) (SE = 9.60) in 2007 and 25.60 prairie dogs per hectare (~10 per acre) (SE = 8.18) in 2008. The mean density across all prairie dog colonies based on the mark-resight technique was 36.43 prairie dogs per hectare (~15 per acre) (SE = 13.00) in 2007 and 33.20 prairie dogs per hectare (~14 per acre) (SE = 5.99) in 2008. The comparison of mark-recapture and mark-resight methods resulted in a t-value of 0.74 (P = 0.724, d.f. = 7) for 2007 and -0.37 (P = 0.482, d.f. = 7) for 2008. The two-sample t-test for prairie dog density across method for both years yielded a t-value of 0.27 (P = 0.796, d.f. = 6). These calculated values led us to conclude that there was no significant difference between our estimates of prairie dog density among methods or years.

Discussion

Severson and Plumb (1998) compared methods to estimate prairie dog density such as visual counts and burrow counts to traditional mark-recapture techniques. They found no significant relationship among burrow counts and the prairie dog population. However, Severson and Plumb (1998) offered a linear model of maximum visual counts as it related to population density ($Y = 3.04 + 0.40X$ [where Y was the maximum visual count and X was the estimated population density]). Also, Severson and Plumb (1998) found that it was not necessary to apply a correction factor to visual count data for prairie dog detectability due to the uniformly, short vegetative structure of their study colonies.

Recent investigations have evaluated the validity of applying the visual count protocol described by Severson and Plumb (1998) for west-central South Dakota to areas beyond the scope of that study (Magle et al. 2007 and Facka et al. 2008). In New Mexico, Facka et al. (2008) found that mark-resight estimates required less effort than traditional mark-recapture studies while providing superior estimates of population size and density. Magle et al. (2007) used mark-resight methods to estimate the population size of prairie dogs on both urban colonies in fragmented habitat and unfragmented habitat of the Pawnee National Grassland in Colorado. They found that transformations of naïve maximum visual counts of prairie dogs fell outside the confidence intervals of their mark-resight estimates in the majority of instances.

Our study supported the use of mark-resight methodology when compared to mark-recapture procedures. The confidence intervals for estimates of population size showed considerable overlap between the mark-resight and mark-recapture methods, which supported our conclusion that there was no significant difference between the two methods in 2007 (Figure 2.1). During 2008 (Figure 2.2) we observed more of the confidence interval overlap described for 2007, which also supported our conclusion that there was no significant difference in the prairie dog density estimates for 2008.

Our estimates of prairie dog density (25.60 – 36.43 prairie dogs per hectare [~ 10 – 15 per acre]) were within the range reported in published studies for the species using mark-recapture or mark-resight approaches (Facka et al. 2008). Hoogland (1995) reported black-tailed prairie dog densities of 6 - 31 individuals per hectare. Severson and Plumb (1998) found the prairie dog density in Badlands National Park and Buffalo Gap National Grasslands, South Dakota to range from 8 - 41 prairie dogs per hectare. Also, at Wind Cave National Park, South Dakota a mean prairie dog density of 43 individuals per hectare was reported by Franklin and Garrett (1989).

We conclude that mark-resight estimates are a valid means by which prairie dog density may be estimated. Similar to mark-recapture estimates, mark-resight estimates allow an investigator to calculate densities based on a proportion of the free-ranging individuals rather than an unreliable proxy, such as burrow density. Overestimation of prairie dog densities may lead to excessive application of toxicants labeled for use to control prairie dogs, which may adversely impact non-target species. Furthermore, overestimating occupied prairie dog habitat has the potential to influence the recovery efforts for species that depend on active prairie dog colony complexes such as the black-footed ferret (*Mustela nigripes*) and burrowing owl (*Athene cunicularia*).

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Table 2.1: Mean density (prairie dogs/hectare) by study colony and method during summers 2007 and 2008, Bad River Ranches, South Dakota.

Colony Number	Mark-Recapture 2007	Standard Error	Mark-Resight 2007	Standard Error
1	5.21	2.59	9.58	2.80
2	32.06	6.78	35.84	4.16
3	14.68	2.53	16.26	2.28
4	60.24	20.10	85.71	15.00
5	35.76	15.40	34.78	15.00
Colony Number	**Mark-Recapture 2008**	**Standard Error**	**Mark-Resight 2008**	**Standard Error**
1	18.33	1.29	17.47	2.77
2	20.26	9.28	12.11	1.53
3	37.18	6.84	29.08	3.43
4	63.42	89.30	46.78	2.43
5	26.83	24.30	22.58	1.14

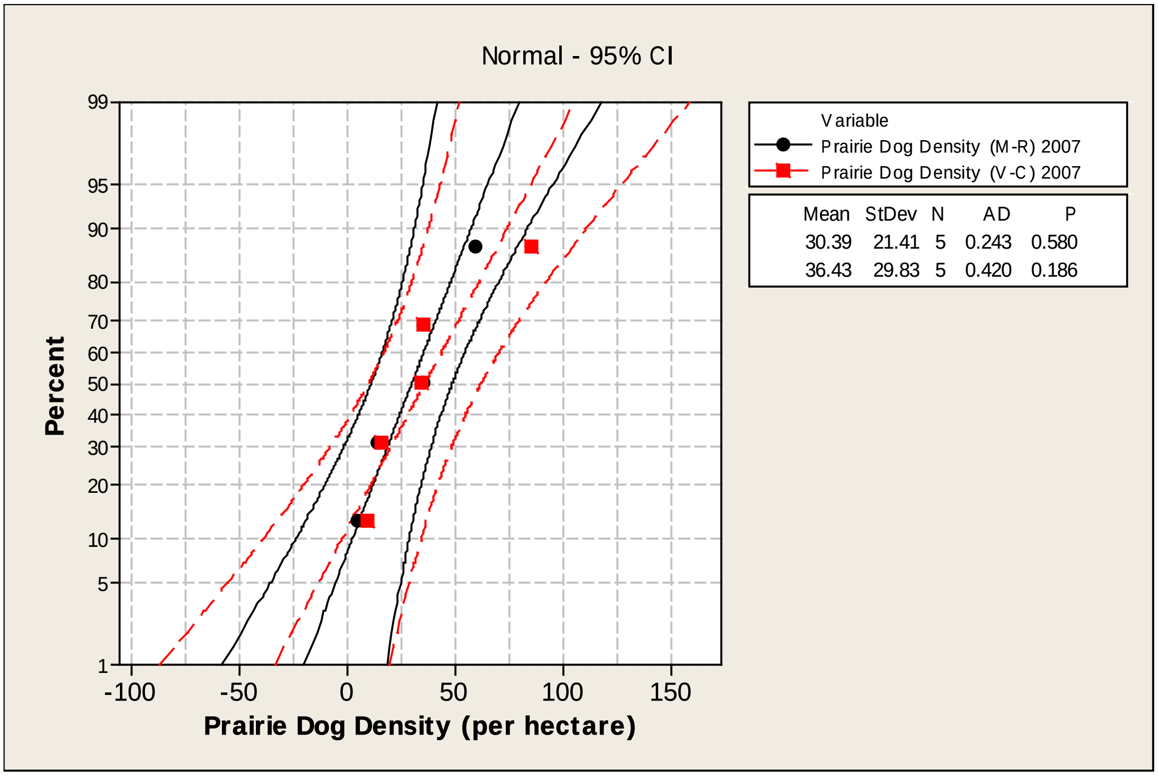

Figure 2.1: Difference in mean black-tailed prairie dog (*Cynomys ludovicianus*) density estimation on replicates by method during summer 2007, Bad River Ranches, South Dakota.

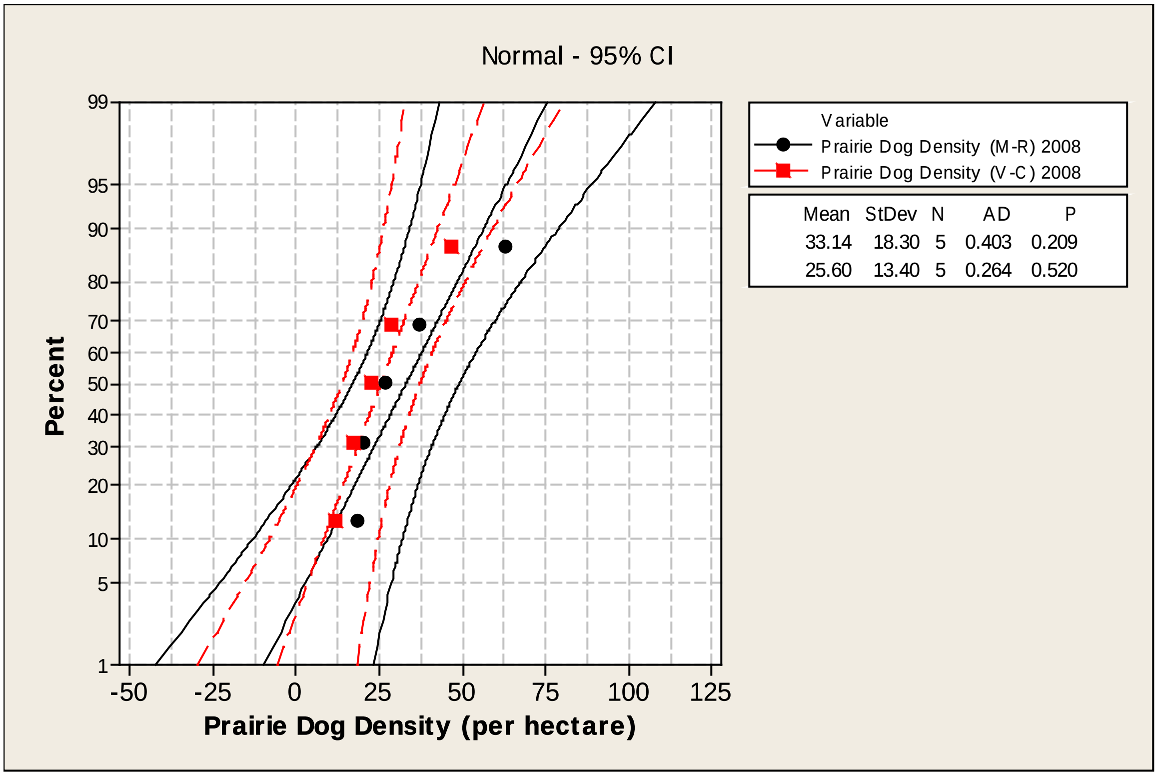

Figure 2.2: Difference in mean black-tailed prairie dog (*Cynomys ludovicianus*) density estimation on replicates by method during summer 2008, Bad River Ranches, South Dakota.

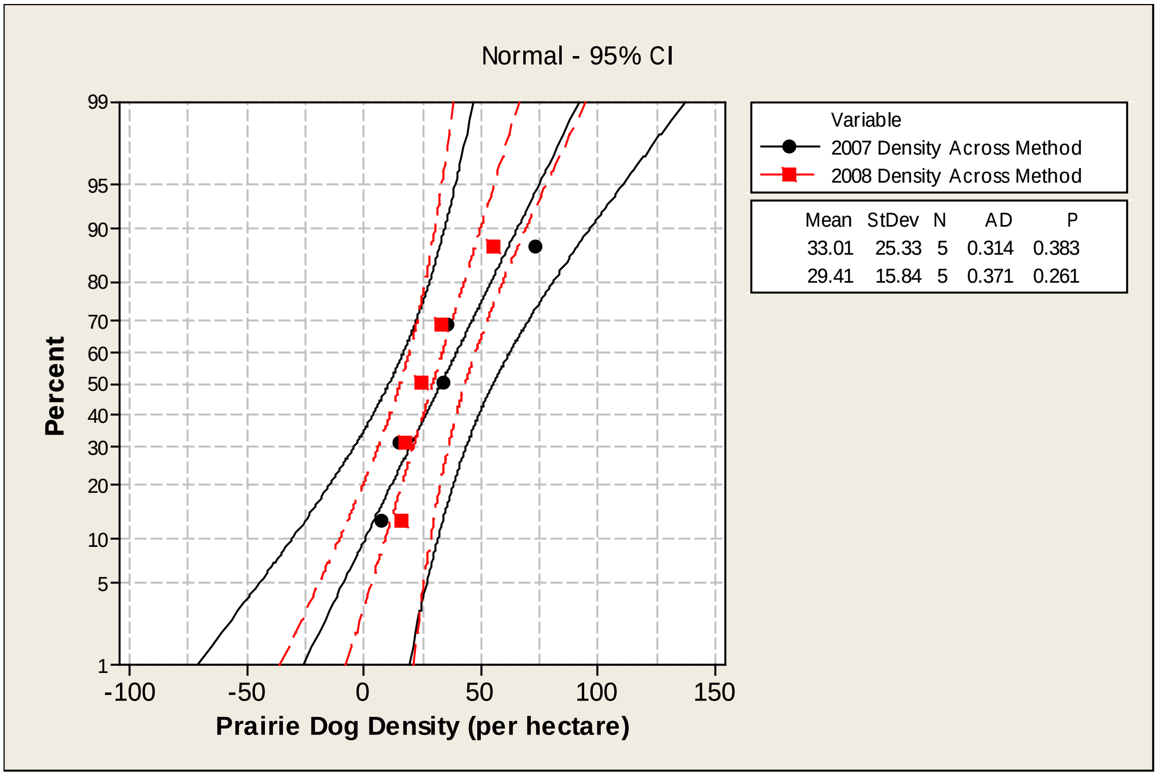

Figure 2.3: Mean black-tailed prairie dog (*Cynomys ludovicianus*) density estimation on replicates by year during summers 2007 and 2008, Bad River Ranches, South Dakota.

Chapter 3

Evaluation of barriers to black-tailed prairie dog (*Cynomys ludovicianus*) colony expansion

Introduction

Black-tailed prairie dogs (*Cynomys ludovicianus*) have traditionally been controlled using lethal techniques, such as shooting and poisoning (Knowles 1986, Klukas 1987, and Merriman et al. 2004). However, the use of non-lethal approaches to limit prairie dog colony expansion has been investigated since the 1980's (Franklin and Garrett 1989). Non-lethal methods of colony management include translocation as well as the establishment of visual and physical barriers to colony expansion (Merriman et al. 2004). These approaches are the result of changing attitudes toward the functions that prairie dogs perform in ecosystems, such as influencing vegetative composition, serving as prey to a wide range of species (i.e., American badger [*Taxidea taxus*], bobcat [*Lynx rufus*], coyote [*Canis latrans*], swift fox [*Vulpes velox*], ferruginous hawk [*Buteo regalis*], rattlesnake [*Crotalus spp*.]), as well as providing nesting or den sites for species, such as the burrowing owl (*Athene cunicularia*) and the federally endangered black-footed ferret (*Mustela nigripes*) (Sharps and Uresk 1990, Wuerthner 1997, and Lomolino and Smith 2003).,

In 2005, the state of South Dakota approved a black-tailed prairie dog conservation and management plan (Cooper and Gabriel 2005; House Bill 1252 and Senate Bill 216, An Act to Mitigate the Impact of Prairie Dogs), which placed stringent restrictions on prairie dog colonies that encroached upon private property where the presence of the species was not desired. According to the State's Plan and Senate Bill 216, a one-mile (1.6 km) buffer zone that is free of prairie dogs must be created and maintained if a formal complaint is registered in response to colony encroachment.

Passage of South Dakota House Bill 1252 and Senate Bill 216 substantially elevated the importance of barrier development in the restoration and management of prairie dogs in South Dakota. Given the modest sizes, irregular configurations, and in-holdings of landowners that characterize most blocks of private property suitable for sustaining prairie dogs, total elimination of prairie dogs within one-mile buffer zones would significantly reduce acreages on which prairie dogs could persist. A reasonable alternative to a one-mile buffer might be the development of barriers that effectively prevent colony encroachment (Bly-Honness et al. 2006, unpublished report).

The objectives of this investigation were to erect physical and visual barriers near property boundaries to reduce expansion rates of black-tailed prairie dog colonies onto adjacent acreages and to monitor the efficacy of such barriers by examining: colony expansion, barrier durability, and barrier cost-effectiveness. Monitoring results were used in an adaptive manner to incrementally improve barrier design. Determining a barrier design type that was most appropriate in terms of durability, cost-effectiveness, and efficacy of limiting prairie dog colony expansion was the major focus of this study.

Study Area

Research was conducted on Bad River Ranches [N44°16.1’ W100°32.0’, ~352 km^2 (~220 mi^2), ~560 m (~1830 ft.)] owned by Turner Enterprises, Inc. in Stanley and Jones counties near Fort Pierre, South Dakota. The ranches were managed for the sustainable production of bison (*Bison bison*) and conservation of native species. The area was characterized as a wheatgrass-needlegrass (*Stipa viridula*) community within the mixed-grass system of the Northern Great Plains (Kuchler 1975). Buffalo grass (*Buchloe dactyloides*) and blue grama grass (*Bouteloua gracilis*) were also widespread (Bly-Honness and Truett, unpublished data). Topography consisted of flat to rolling uplands cut by the Bad River and intermittent drainages. Soils were primarily clays derived from Cretaceous Pierre Shale (Johnson et al. 1995).

Methods

In 2006, we identified five prairie dog colonies as experimental replicates (Figure 3.1). We established visual and physical barriers hypothesized to limit prairie dog colony expansion along pre-existing fence corridors adjacent to property boundaries. At each study colony (replicate), the configuration of four to five treatments (three to four barrier designs and a control) was randomly assigned. However, to reduce the impact of prairie dogs moving around the ends of barriers and introducing bias, there was no gap between barrier treatments and the control was randomly assigned to either end of the barrier arrangement along the fence line. Barriers were 100 m (328 feet) in length and located within monitoring plots 100 m x 100 m (1 ha, 2.47 ac) in area. Barrier types (Figures 3.2 – 3.4) that were evaluated included; vinyl sheeting with chicken wire, natural vegetation (protected from grazing pressure by electrified fencing), and round straw bales. Vinyl sheeting and chicken wire used to establish a fence sufficiently overlapped to maintain barrier integrity along ground level and the seam between the two materials was covered with soil to limit light penetration. Vinyl sheeting used for barriers was a manufactured multi-purpose agricultural material (T-105, Griffolyn Division of Reef Industries, Inc., Houston, Texas) that had been used in urban and suburban prairie dog management in Colorado (City of Fort Collins, Colorado undated). Chicken wire installed in association with the vinyl sheeting was vertically oriented and buried in a trench 30 cm (12 inches) deep with the intent of serving as an anchor for the vinyl as well as limiting the burrowing activities of prairie dogs. Along the length of the vinyl sheeting, metal grommets were located at every meter (3 feet) on top and bottom. The grommets served as a location to attach the vinyl material on the bottom to the chicken wire and on the top to the existing fence using plastic cable ties (Thomas and Betts Corporation, Memphis, Tennessee). Bison exclosures were constructed of electrified tape (Zareba Systems, Inc., Minneapolis, Minnesota), which was attached to metal t-posts driven into the ground and charged by solar units (Gallagher Animal Management Systems, Inc., North Kansas City, Missouri). Round straw bales were oriented end to end in a row along the property boundary, placed tightly together so no gap existed between bales. Straw bales were only incorporated into the study design in 2008 due to the unavailability of bales for 2007 as a result of drought conditions in the region. Furthermore, bales were applied as a treatment only on three of the five study colonies due to weather constraints during placement (heavy rains during the critical time period before juvenile dispersal commenced). An experimental control was located on each colony where no barrier to colony expansion was established. We evaluated the barrier types in relation to the baseline expansion of active prairie dog burrows (breakthroughs) through the control on each colony. We conducted a Chi-square test of the distribution of breakthroughs across the treatments by year.

At the beginning of the investigation (February - March 2007), prairie dogs were removed from the side of the barriers where their presence was not desired by the adjacent landowner to create a zone free of prairie dogs. Additionally, prairie dogs were removed from areas designated for vegetative barriers. Barriers were established in April 2007. At the onset of the second field season, prairie dogs were removed as necessary from the prairie dog free zone on the "neighbor-side" of barriers and necessary repairs to barriers for reestablishment were completed. Prairie dog removal consisted of using a combination of non-lethal and lethal techniques such as translocation, shooting, and rodenticide application. Non-project related shooting was not permitted on the study colonies to prevent unnecessary disturbance of prairie dogs (Pauli and Buskirk 2007). Prairie dogs that moved through barriers were removed at the end of the summer field season, following the recording of active burrow locations with handheld Global Positioning System (GPS) units (Garmin International, Inc., Olathe, Kansas), using the same techniques listed above for establishing the prairie dog free zone. For vegetative barriers, we quantified the distance prairie dogs moved into as well as through the barrier.

Grazing by bison and mechanical mowing were completed on both sides of barriers. Maintaining low vegetative height within the monitoring plots adjacent to barriers was essential to eliminate potential bias created by establishing unintentional barriers to colony expansion that were not included in the investigation and therefore, would confound results. Monitoring plots served as a defined area to record the relative efficacy of barrier design types in relation to one another and to the control in terms of prairie dog breakthroughs. Variables such as weather (mean wind speed [km/hour], wind direction [degrees], precipitation [cm], and temperature [C]), vegetative characteristics (species, composition [%], and height [cm]), prairie dog density (prairie dogs/ha), and rate of expansion (m^2/year) were recorded for each colony within the monitoring plots.

We obtained active growing season (1 April to 31 August) precipitation data for each year of the project as well as one year prior from the South Dakota Office of Climatology (Todey 2009). Other weather data such as temperature, windspeed, and wind direction resulted from direct measurements in the field using a digital thermometer, wind meter (Skywatch Explorer I), and compass. Weather variables were recorded at the same location on each study colony. We recorded temperature, windspeed, and wind direction when visiting a study site to assess barrier efficacy and durability. We visited study sites on a rotating basis to avoid measuring weather variables at the same time of day on any particular colony.

Vegetation sampling generally followed the recommendations of Higgins et al. (1996) and Morrison et al. (2001). We collected data from sample plots using a 0.5 m^2 (~1.64 $feet^2$) frame at 10 random locations along each of 3 transects. Transects were located 30 m (~98 feet) apart. We measured the height of plants within the samples to the effective cover height (i.e., the upper limit of vegetation leafiness). Plant height was measured to the nearest 0.5 cm. Each study colony had 4 to 5 monitoring plots adjacent to the barrier treatments and the control with one occurring within the bison exclosure. This allowed us to determine if the electric fencing facilitated vegetative production. Vegetation was identified to the species level and composition was estimated down to 1% of the sample plot area. The percentage of bare ground also was recorded for each sample (Bly-Honness and Truett, unpublished data).

We estimated prairie dog density on study sites within 3 of the monitoring plots delineated on each colony adjacent to barriers. During 2008, 3 of the 5 colonies had an additional monitoring plot. A 5 x 10 trap grid was established using a total of 50 live-traps per monitoring plot. Traps were 48 cm x 15 cm x 15 cm (19 in x 6 in x 6 in) with a single door (Model 103, Tomahawk Live Trap, Tomahawk, Wisconsin). Following the recommendations of Severson and Plumb (1998), we pre-baited for 3 days prior to commencement of trapping to habituate prairie dogs to the presence of cage traps. Bait used was a commercial horse sweet feed (corn, oats, wheat, barley, alfalpha pellets, and molasses) (Nutrena Feeds, Giddings, Texas). Our trapping sessions were 3-5 days on each colony depending on the ratio of new individuals to recaptures. A buffer zone of 20 m (65 feet) was used to foster independence of the trap grids. Visually dissimilar marking patterns were applied [non-toxic fur dye (RIT Dye, Phoenix Brands, LLC., Stamford, Connecticut)] to prairie dogs in each monitoring plot respectively to allow for capture location identification and thus facilitate population closure. For handling prairie dogs, we constructed a denim handling-sleeve similar to Hoogland (1995). Our handling procedures for prairie dogs were consistent with other studies involving species in the family *Sciuridae* (Hoogland 1995 and Steele and Koprowski 2001). From our mark-recapture and mark-resight data, we calculated an estimate of prairie dog density on each of the 5 study colonies sampled during 2007 and 2008 based on the ratio of marked to unmarked individuals in our samples (King 1955 and Lancia et al. 1996). To reduce potential bias in our estimate, we used the Corrected Lincoln-Petersen Index (n+1) (Lancia et al. 1996). To evaluate the relationship among barrier breakthroughs and prairie dog density, we calculated a Spearman's Correlation Coefficient (rho). Care was taken to comply with the Guidelines for Animal Use in Research (Animal Behavior 1986) and the Acceptable Field Methods in Mammalogy (American Society of Mammalogists 2007). The methods of this investigation were approved (Approval No. 07-A006) by the Institutional Animal Care and Use Committee at South Dakota State University.

We quantified the rate of colony expansion by documenting the maximum distance that breakthroughs occurred beyond barriers. Using ArcView (ESRI, Redlands, California), with imported data collected on handheld GPS units, we measured the distance in meters that active burrows existed beyond barriers. For every treatment plot on each of the five study colonies during 2007 and 2008, we calculated a rate of colony expansion, which we used to determine if there was relationship among the expansion rate and the distribution of breakthroughs that occurred adjacent to each treatment. To evaluate the relationship among barrier breakthroughs and rate of colony expansion, we calculated a Spearman's Correlation Coefficient (rho).

Results

We documented 431 active burrows beyond treatments, 231 occurred within the experimental control. The exclosures and vinyl exhibited 122 and 78 burrows respectively (Figure 3.5). In terms of limiting the number of prairie dog breakthroughs, there was a significant difference among the constructed barrier treatments and the control (F = 5.73, d.f. = 14, P = 0.018), where no barrier was established. The total number of breakthroughs (sum of both treatments and the control) did not vary across the five study sites (F = 1.56, d.f. = 14, P = 0.258). Bison exclosures prevented a significant (t = -4.12, d.f. = 4, P = 0.015) number of breakthroughs when compared to the control as did the vinyl sheeting and chicken wire (t = -4.96, d.f. = 4, P = 0.008).

We found that barriers significantly reduced colony expansion in 2007 (χ^2= 38.55, d.f. = 8, $P \leq 0.001$) and 2008 (χ^2 = 23.30, d.f. = 8, P = 0.003). As a result, we pooled the breakthrough data for 2007 and 2008; barriers contained less breakthroughs than controls (χ^2= 23.98, d.f. = 8, P = 0.0023). Breakthroughs did vary by colony expansion rate for both years (rho = 0.77 [2007], rho = 0.79 [2008], d.f. = 13, $P \leq 0.001$).

Maintenance time was significantly different among treatments; vinyl fencing required more time ($P \leq 0.10$, Figure 3.6) for repairs than the bison exclosure. However, maintenance time for barriers did not vary by study site (P = 0.396). Wind was the largest source of damage to barriers established to limit black-tailed prairie dog colony expansion during the investigation (Figure 3.7). In 2007, windspeed ranged from 24-27 km/h (15-17 mph) with a mean of 24.76 km/h (15.39 mph). Mean windspeed in 2008 was 26 km/h (16.18 mph) with a range of 19-30 km/h (12-19 mph).

During the period from 1 April to 31 August 2007, there were 33.56 cm (13.43 in) of precipitation on the study area (Todey 2009). During the same time period for 2008, weather stations documented 38.19 cm (15.28 in) of precipitation. While these values were similar, a difference in growing season rainfall of 4.63 cm (1.85 in) between 2007 and 2008 modified vegetative production. This information, when coupled with the 15.39 cm (6.16 in) of rainfall quantified from 1 April to 31 August 2006 for the year prior to this investigation, illustrated the impact that the recent precipitation pattern had on vegetative production in 2008.

Across the two years of this study, the overall mean height of vegetation was not significantly different (t = -1.01, P = 0.330, SE = 2.03). However, there was a significant difference (t = 3.28, P = 0.046, SE = 5.86) in the density of vegetative growth in that the percentage of bare ground identified during vegetation surveys decreased from 56% in 2007 to 36% in 2008. Mean height for vegetation inside bison exclosures was similar across the two years (23.43 cm [9.34 in] and 28.13 cm [11.25 in], respectively) (Table 3.2). However, the vegetation within bison exclosures was taller than that of the surrounding monitoring plots [mean = 10.74 cm (4.30 in) for 2007 and mean = 11.14 cm (4.46 in) for 2008] due to the clipping activities of prairie dogs, mowing, and grazing by bison.

We obtained estimates of prairie dog density using two methods on each colony: mark-recapture and mark-resight (Severson and Plumb 1998). The mean prairie dog density across all colonies based on the mark-recapture technique was 29.59 prairie dogs per hectare (~12 per acre) (SE = 9.60) in 2007 and 25.60 prairie dogs per hectare (~10 per acre) (SE = 8.18) in 2008. The mean density across all prairie dog colonies based on the mark-resight technique was 36.43 prairie dogs per hectare (~15 per acre) (SE = 13.00) in 2007 and 33.20 prairie dogs per hectare (~14 per acre) (SE = 5.99) in 2008. To test the distribution of breakthroughs in relation to prairie dog density on each colony, we calculated an additional Spearman's Correlation Coefficient (rho) of -0.98 (d.f. = 13); there was no relationship between prairie dog density and breakthroughs ($P = 0.728$).

Discussion

While previous studies have had mixed results with artificial and natural barriers (Franklin and Garrett 1989, Hyngstrom 1996, Merriman et al. 2004, and Terrall 2006), this project supports the findings of those (Franklin and Garret 1989 and Terrall 2006) that reported successful use of barriers; and will supplement existing information available to managers in the form of offering an evaluation of both artificial and natural barriers established to reduce prairie dog colony expansion rates. We provide a more robust investigation into the subject by incorporating barrier types as replicated treatments on multiple study sites for two field seasons. Non-lethal methods such as barriers may defer the cost associated with poisoning and the time associated with shooting programs, which would provide additional, yet effective, prairie dog management options that are an economical management decision.

During the first year of this investigation, the vinyl sheeting and chicken wire performed better than the bison exclosure and control on every replicate of the study. In the second year, the vinyl was more successful at preventing breakthroughs than the bison exclosure and control on 3 colonies. While the vinyl sheeting and chicken wire was more effective than the bison exclosures erected to facilitate vegetative growth, both treatments reduced the rate of prairie dog recolonization into the areas where the species was not desired. When we pooled the breakthrough data for both years, the vinyl performed better than the exclosure on 3 of the 5 colonies. For 2007 and 2008 combined, the barrier treatments prevented more breakthroughs overall than the control although admittedly not a significant difference for both barrier types on all replicates in both years.

We attribute much of the difference among barrier efficacy between years to circumstances relating to vegetative growth on Colony 2. Access to the colony for mowing was impeded by rain events for an amount of time that allowed the portion of the area prairie dogs occupied (were not removed from) to become dominated by yellow sweet clover (*Melilotus officinalis*) of sufficient height to result in increased prairie dog mortality and site abandonment through dispersal (Knowles 1982). Once the site could be safely mowed, the environmental pressure to move through the barriers and into the area across the fence with less sweet clover had resulted in abandonment of the site by prairie dogs. Colonies 1, 4, and 5 all followed the pattern of breakthroughs described for 2007 during 2008.

Terrall (2006) used natural vegetative buffer strips of varying widths as barriers to prairie dog colony expansion. We provided evidence to support the buffer width model output presented by Terrall (2006). We demonstrated that a buffer width of 100 m (328 feet) significantly reduced the recolonization rate of suitable habitat by prairie dogs in areas where optimal vegetative height and density may be lacking. The conditions in central South Dakota during this study were not conducive to producing a vegetation height of 40 cm, which was identified by Terrall (2006) as necessary to limit prairie dog expansion in western South Dakota.

Investigations have incorporated artificial barrier designs and have shown them to be unsuccessful at limiting prairie dog colony expansion (Hyngstrom 1996 and Merriman et al. 2004). Merriman et al. (2004) indicated that galvanized roofing material and commercial silt fence failed to prevent prairie dog expansion. Hyngstrom (1996) concluded that plastic snow fencing was ineffective at limiting prairie dog colony expansion. The ability of prairie dogs to see through the barriers due to materials and construction techniques as well as the vulnerability of barriers to damage caused by environmental factors are reasons cited for the potential inadequacy of artificial barriers. In this study, we followed the recommendations of Hyngstrom (1996) by selecting an artificial barrier material that had low light penetration and was secured along the ground in a trench. We documented that the vinyl fencing sustained damage mostly from wind. Much of the damage to vinyl prairie dog barriers requiring maintenance could be reduced if more durable attachments to the existing fence are used (i.e., metal hog rings) rather than plastic cable ties.

Franklin and Garret (1989) experimented with cut ponderosa pine (*Pinus ponderosa*) trees and successive rows of burlap material (1-m high) in Wind Cave National Park, South Dakota. The authors found that artificial barriers (burlap) reduced the rate of prairie dog colony expansion with an expansion rate of 8% for the treated areas and 54% for control areas. Furthermore, the cut pine treated areas successfully limited prairie dog colony expansion, likely due to the visual and physical influence of the barriers on the movements of individuals. We found that both a natural barrier (vegetation protected from grazing by electric fencing) and an artificial barrier (vinyl sheeting and chicken wire) were successful at limiting prairie dog colony expansion. We attributed the success of the natural barrier to the width of the buffer rather than visual obstruction due to poor vegetative growth (Terrall 2006). The superior ability of the artificial barrier to limit the passage of light through the material resulted in the low visibility of adjacent, yet unoccupied, habitat to prairie dogs as recommended by Hyngstrom (1996).

Straw or hay bales have been suggested for use as visual barriers to reduce prairie dog colony expansion rate (Franklin and Garret 1989 and Hyngstrom and Virchow 1994). While excluded from our analyses, we attempted to incorporate round straw bales as a prairie dog barrier treatment. We only applied large round straw bales in 2008 on 3 of 5 sites. Unexpectedly, the straw bale barrier exhibited 97 breakthroughs. Given the impact of limited data on straw bales, we are unable to make inferences regarding bales as a barrier to prairie dog colony expansion. However, if we were to adjust the number of breakthroughs for 2008 by the mean number of events for the colonies on which bales were present and then double it, the resulting number (n=323) would preclude a recommendation of straw bales as an effective barrier to prairie dog movement. In fact, members of our crew observed prairie dogs climbing over as well as burrowing through bales to gain an advantageous vantage point for scanning the colony.

We did not document a significant difference in mean vegetation height among years. We attribute the similarity in vegetation height across years to the biological potential of the plant community that grows in central South Dakota. The first year of this study was considered a drought year in a series of growing seasons with below average rainfall. The second year of this study was not considered a drought year (Tom LeFaive, Ranch Manager – Bad River Ranches, pers. comm.). The vegetation within bison exclosures was taller than the portions of the colonies that were grazed by bison and mowed. There was a significant difference in the density of vegetation in that the percentage of bare ground documented in 2007 decreased by 20% in 2008. Increase in vegetative production was the result of increased precipitation from 2005 to 2008 (Todey 2009).

One of our research objectives was to determine the cost-effectiveness of the respective barrier designs (Figure 3.11). The cost of vinyl sheeting and chicken wire was $898.68 per 100 m (328 feet). The cost associated with bison exclosures was $341.93 per 100 m (328 feet). Overall, the vinyl sheeting and chicken wire was more effective than the bison exclosures at reducing prairie dog recolonization, however, both treatments were more effective than no barrier at all (experimental control). Information that must be considered when selecting a prairie dog barrier includes maintenance time involved for the treatment to remain effective. We found that the vinyl sheeting and chicken wire required more maintenance time than the bison exclosures ($P \leq 0.10$).

Overall, the barrier treatments reduced prairie dog colony expansion by limiting the number of breakthroughs when compared to control areas. Our study represents a maximum relative to breakthroughs because of the length of the treatments. In a non-experimental application, treatments would form a homogenous and contiguous obstruction (visually and physically) to prairie dog colony expansion. Barriers would extend completely across the colony and into adjacent unsuitable habitat to reduce the likelihood of movements around the ends of a treatment. To appropriately evaluate prairie dog barriers, it was necessary to include all treatments on all replicates to increase the statistical rigor of our analyses.

Difference in cost, efficacy, and maintenance of the barrier types may result in different levels of appropriateness depending on the situation where prairie dog barriers will be installed due to: the size of the barrier project, size of installation and maintenance crew, landowner requests, or funding agency. Each situation where a prairie dog conflict occurs may be different from the next. Not all management techniques are consistent with the objectives of the property being managed. It is the responsibility of the manager to decide which control method or combination of methods (lethal and non-lethal) to employ on a given site at a given time to successfully balance the needs of stakeholders while maintaining prairie dogs on the landscape.

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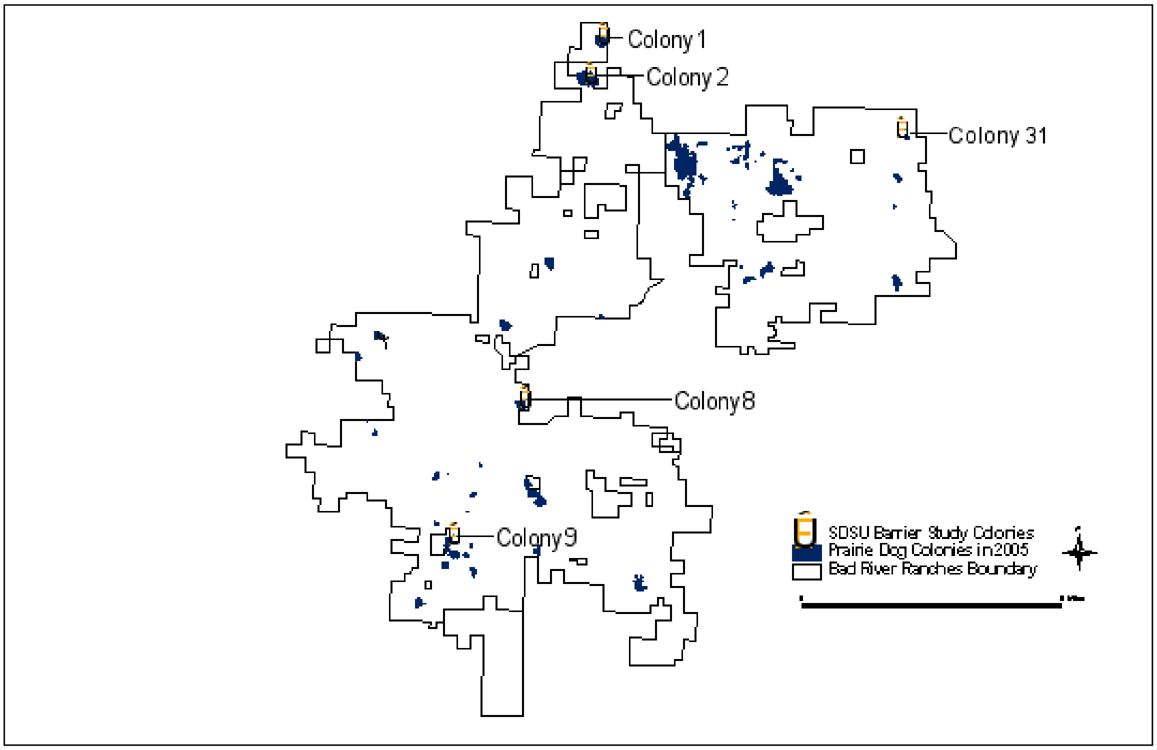
Table 3.1: Mean density (prairie dogs/hectare) by study colony and method during summers 2007 and 2008, Bad River Ranches, South Dakota.

Colony Number	Mark-Recapture 2007	Standard Error	Mark-Resight 2007	Standard Error
1	5.21	2.59	9.58	2.80
2	32.06	6.78	35.84	4.16
3	14.68	2.53	16.26	2.28
4	60.24	20.10	85.71	15.00
5	35.76	15.40	34.78	15.00
Colony Number	**Mark-Recapture 2008**	**Standard Error**	**Mark-Resight 2008**	**Standard Error**
1	18.33	1.29	17.47	2.77
2	20.26	9.28	12.11	1.53
3	37.18	6.84	29.08	3.43
4	63.42	89.30	46.78	2.43
5	26.83	24.30	22.58	1.14

Table 3.2: Summary of vegetation sampling data collected by barrier monitoring plot for summers 2007 and 2008 (Pooled across sites), Bad River Ranches, South Dakota.

Monitoring Plot	**2007 Mean Height (cm)**	**Standard Error**	**2007 Bare Ground (%)**	**Standard Error**
Ea	23.34	4.44	35	8.35
Eb	10.45	0.93	55	10.70
V	9.66	1.91	69	5.08
C	12.12	2.92	63	6.06
Monitoring Plot	**2008 Mean Height (cm)**	**Standard Error**	**2008 Bare Ground (%)**	**Standard Error**
Ea	28.13	3.04	26	3.71
Eb	10.70	1.33	45	9.01
V	11.43	0.68	36	5.76
C	11.72	1.28	35	5.05

*Ea = within bison exclosure, Eb = adjacent to bison exclosure, V = adjacent to vinyl sheeting and chicken wire, C = adjacent to control.



Map courtesy of Kristy Bly, Turner Endangered Species Fund

Figure 3.1: Study area and study sites included in the project: Evaluation of barriers to black-tailed prairie dog (*Cynomys ludovicianus)* colony expansion, Bad River Ranches, South Dakota.

Figure 3.2: Vinyl sheeting and chicken wire installation as a barrier to black-tailed prairie dog (*Cynomys ludovicianus)* colony expansion during summers 2007 and 2008, Bad River Ranches, South Dakota.

Figure 3.3: Bison exclosure to facilitate the growth of vegetative barriers to black-tailed prairie dog (*Cynomys ludovicianus*) colony expansion during summers 2007 and 2008, Bad River Ranches, South Dakota.

Figure 3.4: Straw bales as a barrier to black-tailed prairie dog (*Cynomys ludovicianus)* colony expansion during summer 2008, Bad River Ranches, South Dakota.

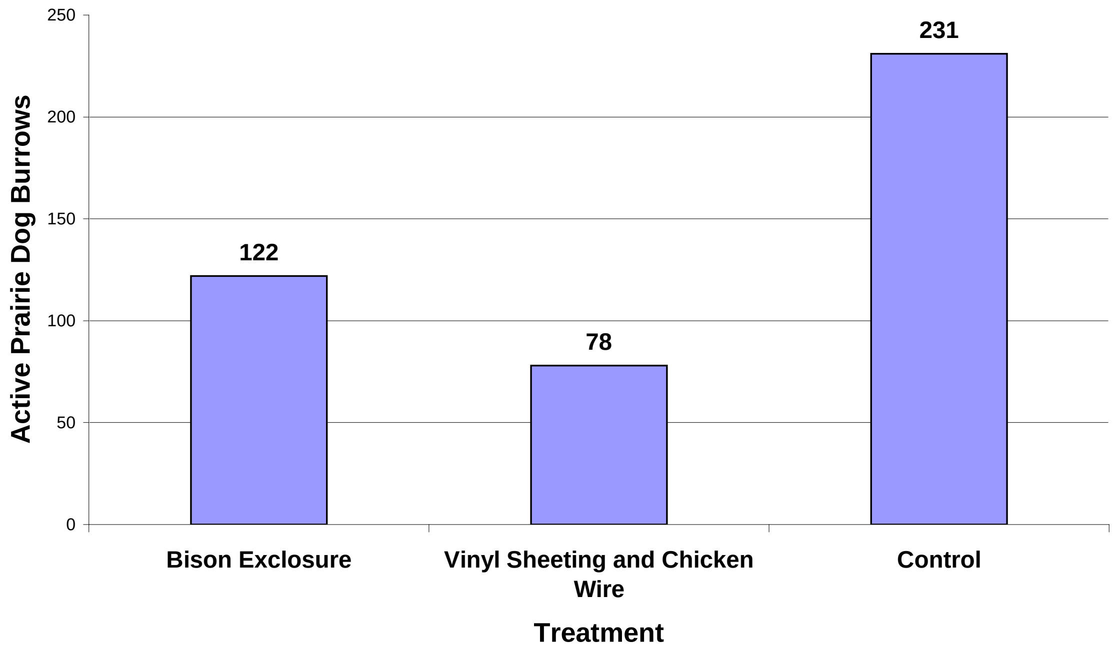


Figure 3.5: Total black-tailed prairie dog (*Cynomys ludovicianus*) barrier breakthroughs by treatment during summers 2007 and 2008, Bad River Ranches, South Dakota.

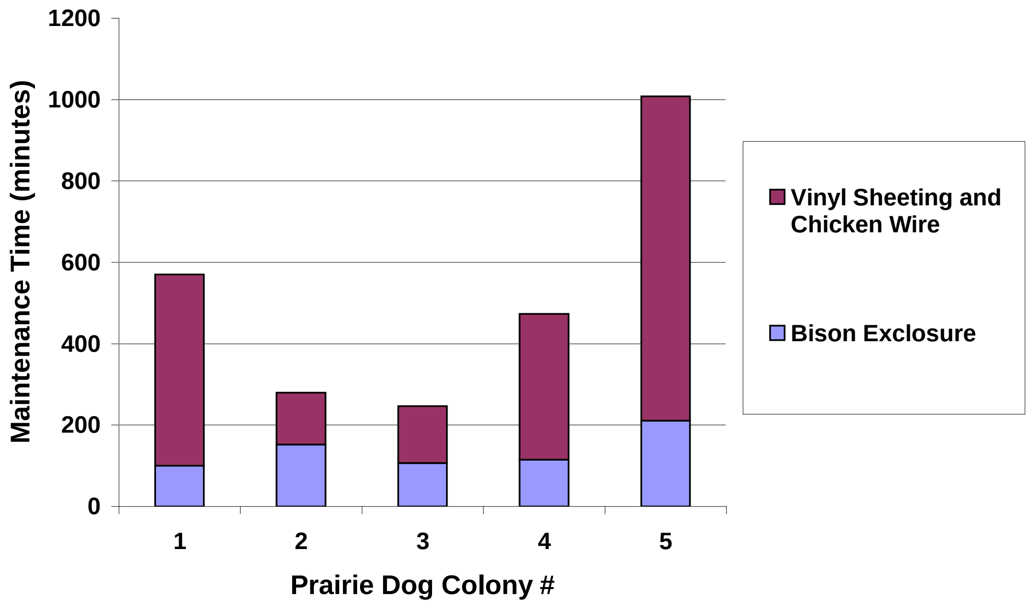


Figure 3.6: Black-tailed prairie dog (*Cynomys ludovicianus*) barrier maintenance time by treatment during summers 2007 and 2008, Bad River Ranches, South Dakota.

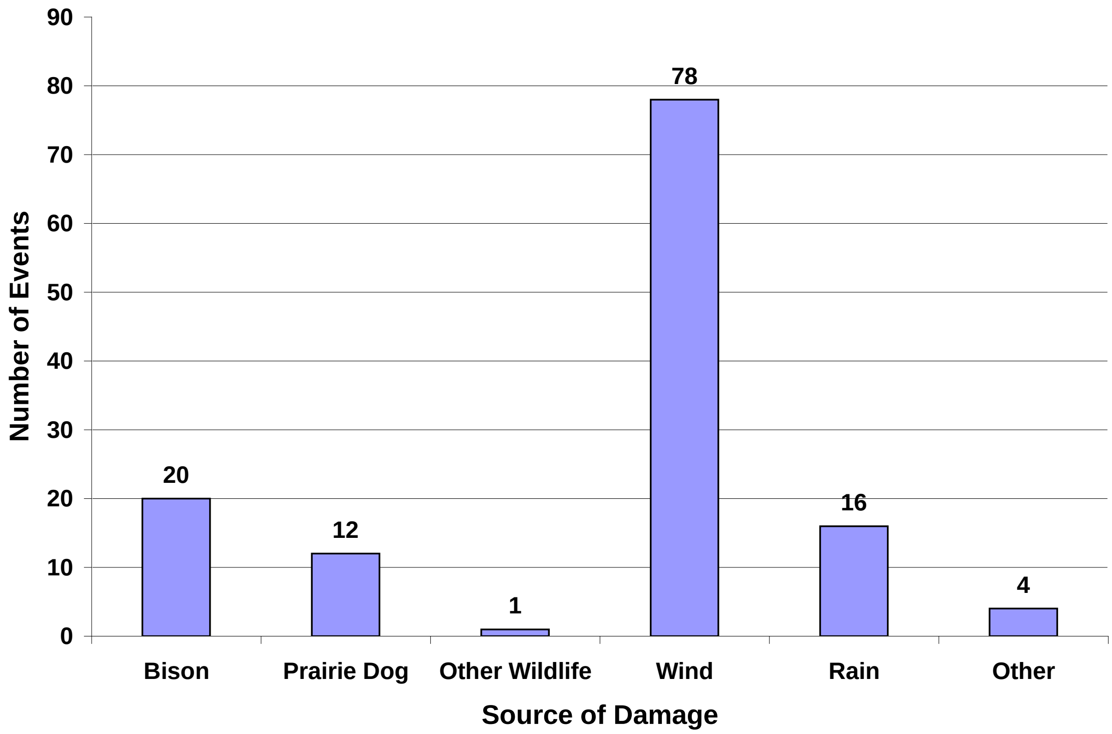


Figure 3.7: Cause-specific damage to black-tailed prairie dog (*Cynomys ludovicianus*) barriers during summers 2007 and 2008, Bad River Ranches, South Dakota.

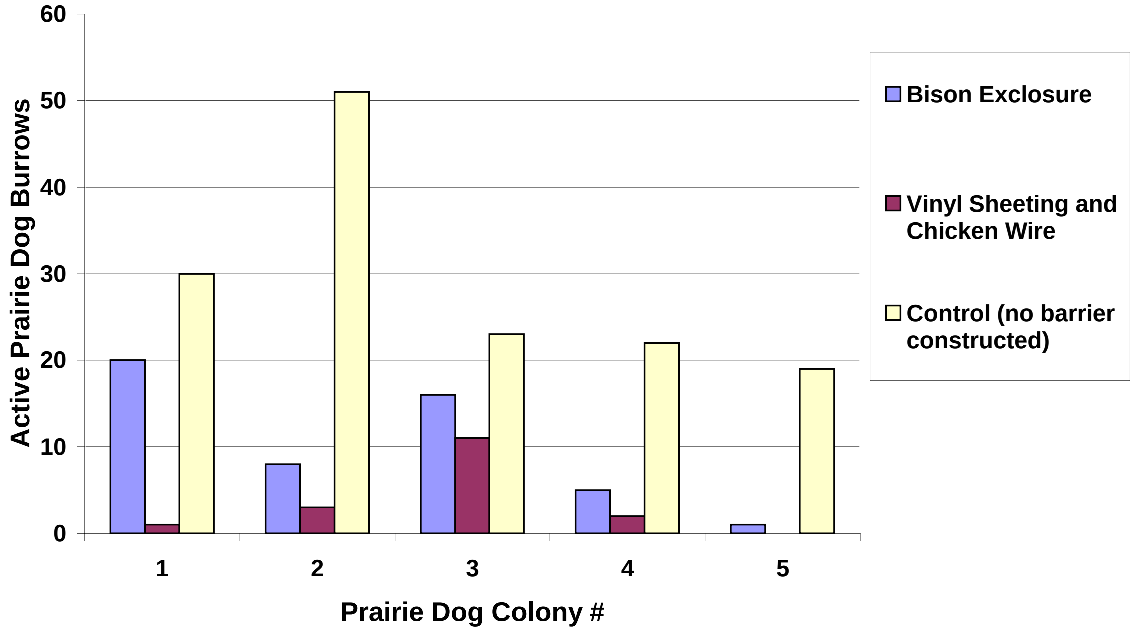


Figure 3.8: Black-tailed prairie dog (*Cynomys ludovicianus*) barrier breakthroughs by study site during summer 2007, Bad River Ranches, South Dakota.

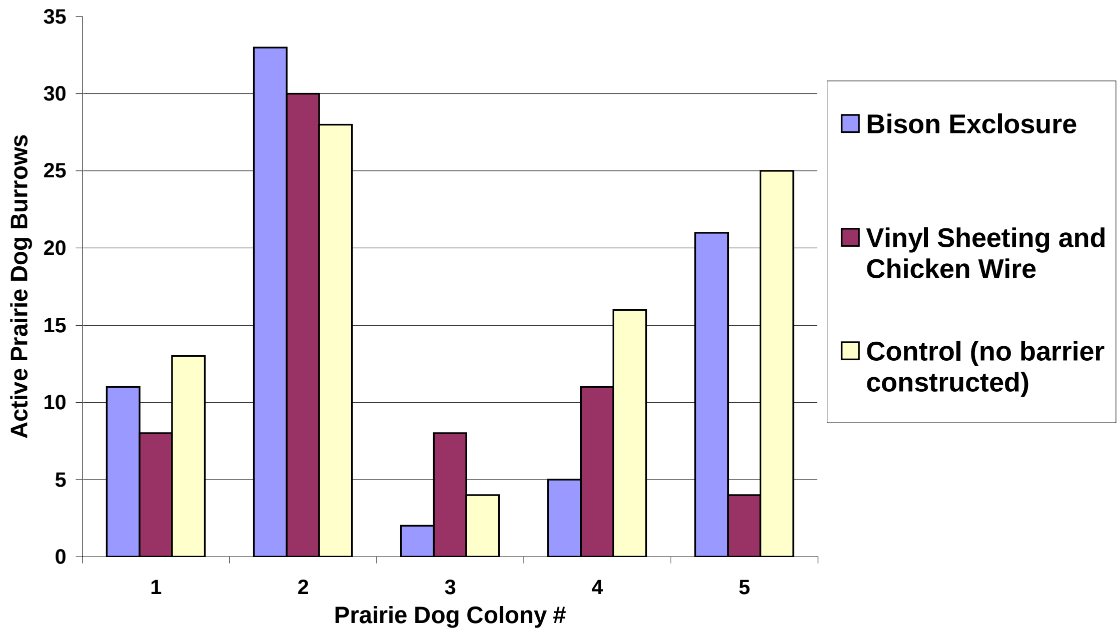


Figure 3.9: Black-tailed prairie dog (*Cynomys ludovicianus*) barrier breakthroughs by study site during summer 2008, Bad River Ranches, South Dakota.

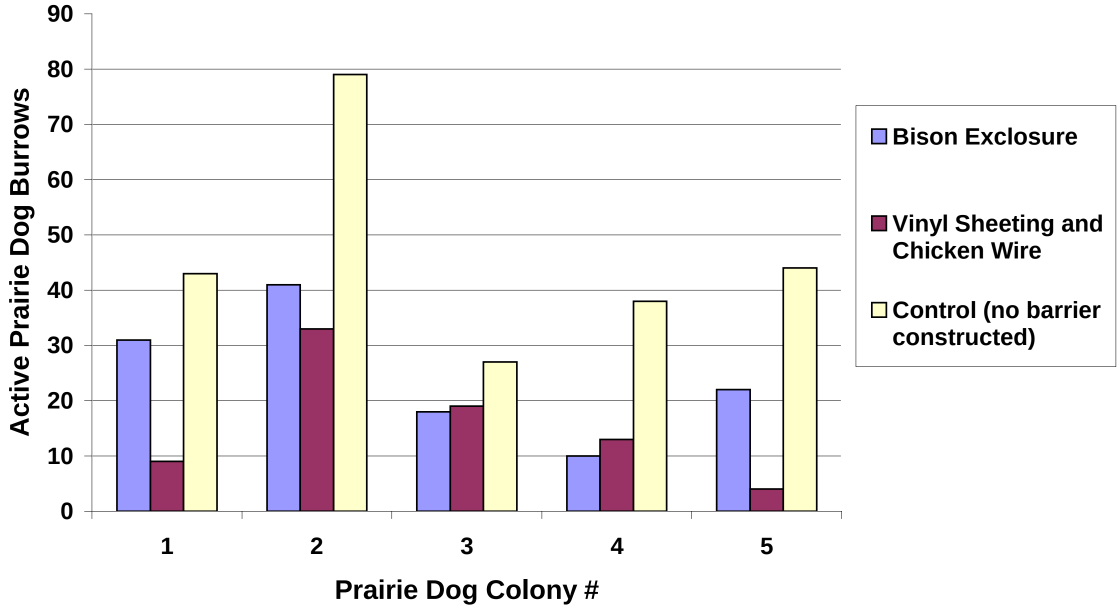


Figure 3.10: Pooled black-tailed prairie dog (*Cynomys ludovicianus*) barrier breakthroughs by study site during summers 2007 and 2008, Bad River Ranches, South Dakota.

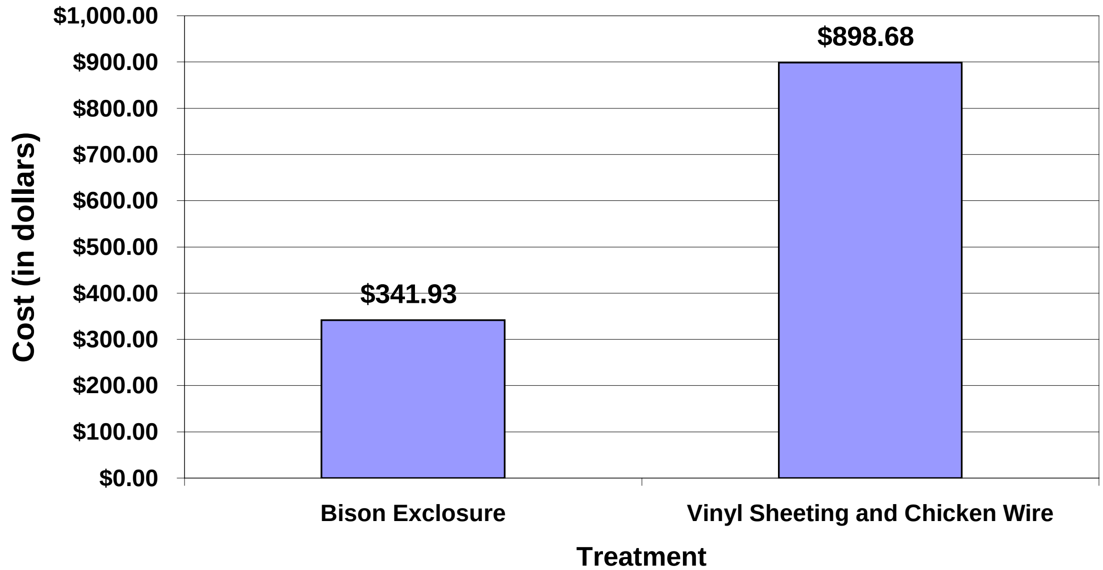


Figure 3.11: Black-tailed prairie dog (*Cynomys ludovicianus*) barrier materials cost by treatment (per 100 meters) during summers 2007 and 2008, Bad River Ranches, South Dakota.

Chapter 4

Management Implications and Conclusions

The black-tailed prairie dog (*Cynomys ludovicianus*) has been traditionally controlled using lethal techniques, such as shooting and poisoning (Knowles 1986, Klukas 1987 and Merriman et al. 2004). However, the use of non-lethal approaches to limit prairie dog colony expansion has been investigated since the 1980's (Franklin and Garrett 1989). Non-lethal methods of colony management include translocation as well as the establishment of visual and physical barriers to colony expansion (Merriman et al. 2004). These approaches are the result of changing attitudes toward the functions that prairie dogs perform in ecosystems, such as influencing vegetative composition, serving as prey to a wide range of species (i.e., American badger [*Taxidea taxus*], bobcat [*Lynx rufus*], coyote [*Canis latrans*], swift fox [*Vulpes velox*], ferruginous hawk [*Buteo regalis*], rattlesnake [*Crotalus spp*.]), as well as providing nesting or den sites for species, such as the burrowing owl (*Athene cunicularia*) and the federally endangered black-footed ferret (*Mustela nigripes*) (Sharps and Uresk 1990, Wuerthner 1997, and Lomolino and Smith 2003).

While previous studies have had mixed results with artificial and natural barriers (Franklin and Garrett 1989, Hyngstrom 1996, Merriman et al. 2004, and Terrall 2006), this project supplemented existing information available to managers in the form of offering an evaluation of both artificial and natural barriers established to reduce prairie dog colony expansion rates. We offer a more robust investigation into the subject by incorporating barrier types as replicated treatments on multiple study sites for two field seasons. Non-lethal methods such as barriers may defer the cost associated with poisoning and the time associated with shooting programs that would provide additional, yet effective, prairie dog management options that are an economical management decision.

Overall, in this investigation, the barrier treatments reduced prairie dog colony expansion by limiting the number of breakthroughs when compared to no barrier at all. Our study represents a maximum relative to breakthroughs because of the length of the treatments. In a non-experimental application, treatments would form a homogenous and contiguous obstruction (visually and physically) to prairie dog colony expansion. Barriers would extend completely across the colony and into adjacent unsuitable habitat to reduce the likelihood of movements around the ends of a treatment. To appropriately evaluate prairie dog barriers, it was necessary to include all treatments on all replicates to increase the statistical rigor of our analyses.

The cost of vinyl sheeting and chicken wire was \$898.68 per 100 m (328 feet). The cost associated with bison exclosures was \$341.93 per 100 m (328 feet). Overall, the vinyl sheeting and chicken wire was more effective than the bison exclosures at reducing prairie dog recolonization, however, both treatments were more effective ($P = 0.0023$) than no barrier at all (experimental control). Information that must be considered when selecting a prairie dog barrier is the maintenance time involved for the treatment to remain effective. We found that the vinyl sheeting and chicken wire required more maintenance time than the bison exclosures ($P \leq 0.10$).

Difference in the cost, efficacy, and maintenance of the barrier types may result in different levels of appropriateness depending on the situation where prairie dog barriers will be installed due to: the size of the barrier project, size of installation and maintenance crew, landowner requests, or funding agency. Each situation where a prairie dog conflict occurs may be different from the next. Not all management techniques are consistent with the objectives of the property being managed. It is the responsibility of the manager to decide which control method or combination of methods (lethal and non-lethal) to employ on a given site at a given time to successfully balance the needs of stakeholders while maintaining prairie dogs on the landscape.

Due to the sensitive political circumstances surrounding the issue of prairie dog management and the ecological influence of the species, identifying barrier types that effectively limit colony expansion was of utmost importance. For the black-tailed prairie dog to be restored, or otherwise conserved in an ecologically significant manner, we recommend that the species be permitted to occupy as much area as practicable on public and private land where its presence is desired or not perceived as a pest in need of immediate extermination (Hoogland 2007). Conversely, great care must be taken to limit colony expansion onto lands where the presence of the prairie dog is not desired as an effort to reduce potential impacts such as economic loss through crop depredation. It is hoped that the frequency, intensity, and therefore, cost associated with lethal methods of prairie dog control will be deferred as removal techniques will no longer be the sole methods of affordable and effective prairie dog colony management. Using non-lethal methods of prairie dog management in conjunction with traditional lethal methods of control is a benefit to managers seeking to successfully mediate the concerns of their constituents and other stakeholders in the issue as professional and public attitudes toward the species change over time.

Considerable disagreement exists in the literature concerning the most appropriate technique to estimate black-tailed prairie dog (*Cynomys ludovicianus*) density (Magle et al. 2007 and Facka et al. 2008). Agencies that manage prairie dogs have disparate modes of estimating density and occupancy rates of the species across its range. Techniques employed include: burrow counts, mark-recapture, and visual counts. Burrow counts are either conducted as an aerial or ground survey and use a ratio of active to inactive burrows as a surrogate for the true number of individuals for a designated area. While the relationship among burrow counts and prairie dog density has been shown to be invalid (Severson and Plumb 1998), the technique continues to be employed (Fagerstone et al 2005, Gershman et al 2005 and Bly 2006).

In our study, we documented that mark-recapture and mark-resight techniques provided similar estimates of prairie dog density across methods and years. We provided support for mark-resight estimates being used as a valid means by which prairie dog density may be estimated. Similar to mark-recapture estimates, mark-resight estimates allow an investigator to calculate densities based on a proportion of the free-ranging individuals rather than an unreliable proxy, such as burrow density. Overestimation of prairie dog densities may lead to excessive application of toxicants labeled for use to control prairie dogs, which may adversely impact non-target species. Furthermore, overestimating occupied prairie dog habitat has the potential to influence the recovery efforts for species that depend on active prairie dog colony complexes such as the black-footed ferret (*Mustela nigripes*) and burrowing owl (*Athene cunicularia*).

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