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SCAMPERING IN THE CITY:
EXAMINING THE ECOLOGICAL AND SOCIAL VIABILITY OF BLACK-TAILED
PRAIRIE DOGS (*CYNOMYS LUDOVICIANUS*) IN DENVER, COLORADO

A Thesis

Presented to the
Faculty of Natural Sciences and Mathematics
University of Denver

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts

by

Lauren K. Morse

June 2010

Advisor: Dr. Rebecca Powell

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Title: SCAMPERING IN THE CITY: EXAMINING THE ECOLOGICAL AND SOCIAL VIABILITY OF BLACK-TAILED PRAIRIE DOGS (*CYNOMYS LUDOVICIANUS*) IN DENVER, COLORADO

Advisor: Dr. Rebecca L. Powell

Degree Date: June 2010

ABSTRACT

The conservation of prairie dogs is highly contested due to the embedded view that they are pests. This research addressed the ecological and social viability of prairie dog colonies in Denver, Colorado. Remote sensing analysis was applied to identify potentially viable areas for urban prairie dog colonies. In order to assess the social viability of urban colonies, knowledge and attitudinal surveys were distributed to residents near existing colonies and residents near potential colonies. Statistical analysis of responses provided insight into relationships between proximity to colonies, ecological knowledge, attitudes towards prairie dogs, demographics, and the presence of educational literature. Results indicated that women are consistently more favorable towards prairie dogs; knowledge was strongly associated with favorability towards prairie dogs; and residents living near colonies were more favorable towards local prairie dogs than residents living near potential colonies. While additional education and outreach is necessary in order to improve residents' attitudes towards prairie dogs, this species has the potential to be viable in Denver.

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Introduction

We inhabit an urban world. A slight majority of the world's population now lives in cities; a sizable majority of Americans inhabit urban areas. Cities are burgeoning in both extent and population (Potere et al. 2009). Edge cities and suburbs further contribute to an increasing dominance of the built environment (Wolch 2007, Garreau 1992). As these concrete structures and asphalt thoroughfares annex the surrounding countryside, humans frequently come into contact and conflict with wildlife inhabiting the urban fringe. However, many generalist species¹ have long made their home in cities, nesting in nooks and crannies, swiping garbage, and slinking from park to park along riparian corridors. While some of these opportunistic species are more or less accepted as part of the urban landscape (e.g., squirrels), many species seem entirely incongruous with contemporary conceptions of an urban landscape. Indeed, most American cities are:

“...culturally fragmented arenas in which values and attitudes towards nature in general (and wildlife in particular) are bound to be highly variable...Metropolitan areas are also spatially extensive, patchy landscapes whose constituent parts are poorly articulated, politically autonomous, and subject to weak regional regulation with respect to land use control and habitat conservation” (Wolch et al. 1995, 737).

¹ A generalist species can thrive in a wide range of environments due to flexibility in diet and habitat.

Urban residents hold varying perceptions of what should be urban and what should be wild. Opinions about urban wildlife range from conservation-oriented to apathetic to preferences for lethal management practices (Lybecker et al. 2002). Therefore, the presence of urban wildlife can become hotly contested, particularly when the species in question is historically despised. As a result of rapid urban expansion and wide divergence in viewpoints about urban wildlife, managing and preserving open space for wildlife becomes extremely difficult.

Colorado's Front Range is no exception. This area has undergone phenomenal metropolitan growth, evolving into a mosaic landscape of remnant prairie, highways, big-box stores, shopping malls, and moderately-dense downtowns. The population of the Denver-Aurora metropolitan area alone has increased by fifteen percent—an addition of over 300,000 residents—since 2000 (U.S. Census Bureau 2009). This urban growth engulfs and fragments prairie ecosystems, as well as associated species (Magle & Crooks 2009).

In addition to the challenges posed by dwindling space, black-tailed prairie dogs² are widely considered destructive vermin, in large part due to a long regional history of ranching and agriculture. They have been and still are routinely and systematically poisoned throughout Colorado; yet, some manage to eke out a living in marginal urban habitat—including highway medians. When white American settlers first moved

² *Cynomys ludovicianus* will hereafter be referred to as prairie dogs.

westward, there were over five billion prairie dogs with colonies stretching for thousands of acres (Hoogland 1995). Today, about one percent of that historical population remains. Despite the entrenched hatred towards prairie dogs, especially in the Western United States, this keystone species is vital to the health of the prairie ecosystem.

Most of prairie dogs' keystone functions (e.g., burrowing) have been documented in rural complexes covering thousands of acres. Comparatively, urban prairie dog colonies are small and fragmented. Nevertheless, urban colonies can be an important prey source for charismatic local populations of golden eagles (*Aquila chrysaetos*), ferruginous hawks (*Buteo regalis*), and red-tailed hawks (*Buteo jamaicensis*) (Hoogland 2006). They are also important prey for coyotes (*Canis latrans*). Small urban colonies could increase public awareness of prairie dogs and their vital role in providing food and habitat for numerous grassland species. More broadly, urban wildlife and native habitat spaces enhance property values (Magle & Crooks 2009) in addition to reducing stress and crime (James et al. 2009).

While urban prairie dog colonies should ideally connect residents to the native prairie landscape which has largely disappeared from Denver region, they can be hot spots for conflict. Residents express fear of disease, specifically the plague,³ which is carried by fleas and transmitted to prairie dogs. The presence of plague tends to rapidly wipe out prairie dog colonies. While the risk of transmission from humans to prairie dogs

³ Whenever the plague is referred to in this work, I am referring to sylvatic or bubonic plague (*Yersinia pestis*).

is extremely low, fear of this disease is embedded in urban inhabitants. Prairie dogs will forage in yards during times of drought, so residents may also fear landscape damage (A. DeLaup, wildlife ecologist, personal communication, Feb. 2010).

Despite these challenges, the Parks & Recreation Department of the City and County of Denver, Colorado, is creating a prairie dog management plan (A. DeLaup, wildlife ecologist, personal communication, Feb. 2009) and attempting to support its current prairie dog colonies in order to provide prey sources for local predators (A. DeLaup, wildlife ecologist, personal communication, Feb. 2010). The Parks & Recreation Department is also trying to determine viable relocation sites in order to avoid additional poisoning of local colonies (A. DeLaup, wildlife ecologist, personal communication, Feb. 2010).⁴ In order to be successful over the long-term, the city must cope with the inevitable human-wildlife conflicts.

In order to determine how prairie dogs can be sustained over the long-term in Denver's urban landscape matrix, suitable open space sites must be found and actively preserved. Yet, successful restoration and maintenance of prairie dog populations does not depend on ecology alone—how society recognizes and values prairie dogs will play a pivotal role in the future of the species. Urban wildlife conflict is a significant issue for this species, as historical stereotypes influence the public sentiment against prairie dogs.

⁴ While the City & County of Denver has not poisoned colonies on public lands in several years, poisoning is typically used by developers when land is zoned for development or by private landowners when prairie dogs expand beyond natural areas onto private property (A. DeLaup, wildlife ecologist, personal communication, Feb. 2010).

Therefore, social criteria must also be evaluated as an additional limitation to prairie dog distribution in an urban landscape. While urban wildlife provides notable ecological and cultural benefits for metropolitan residents and visitors, these benefits are often obscured or unnoticed. It is my goal to determine the distribution of viable open spaces for potential prairie dog habitat—in conjunction with relationships between demographics, ecological knowledge, and residential attitudes—in order to comprehensively examine the long-term viability of urban prairie dogs. Given these ecological realities and social constraints, my research aims to broadly address the following question: Can prairie dogs in Denver be viable over the long-term with regards to both ecological and social criteria?

Background on the Species of Interest

Prairie Dogs: The Life of a Keystone Species

Prairie dogs are social, burrowing rodents. They live in colonies which were historically linked together in a larger complex (Hoogland 1995). Black-tailed prairie dogs, the largest of the five prairie dog species,⁵ have beige bodies with a black-tipped tail. Prairie dogs are active only during the daytime, kissing each other in greeting, chattering incessantly, clipping vegetation, maintaining burrows, watching for predators, and scampering between the many burrow entrances within a family's territory. They descend into their burrows at night.

Prairie dogs breed once a year; females generally have litters of three pups that emerge from the burrow in the early summer (Hoogland 2006). Survivorship of the first year is less than 55% (Hoogland 2006). Infanticide perpetrated by adult prairie dogs, predation, and inability to survive the winter months account for most of the mortality rate (Hoogland 2006). Therefore, prairie dogs generally have a slow population growth rate.

⁵ The other species are commonly known as Gunnison's prairie dog, the Utah prairie dog, the Mexican prairie dog, and the white-tailed prairie dog. The Utah and Mexican prairie dog are classified as threatened and endangered, respectively.

Prairie dogs prefer a very distinct landscape for their colonies. They are generally found in the short and mixed grass prairie, where they alter the landscape by clipping the vegetation and digging burrows. These rodents occupy areas characterized by deep soil, few rocks, low flooding potential, and flat land with a slope of less than 10 degrees (Long 2002, Proctor et al. 1998, Proctor et al. 2006). Prairie dogs need to see approaching predators, and thus will engineer the surrounding vegetation and their burrow mounds to allow high visibility. Many prairie dogs will disperse from their natal colony at some point, and juvenile males routinely disperse, but they usually do not travel further than five to seven kilometers (around 3.1 to 4.3 miles) (Hoogland 2006). In order to maintain genetic diversity, it is important for individual colonies to maintain some connectivity to other colonies within a larger complex (Magle & Crooks 2009).

Prairie dogs have the most advanced language documented in non-human mammals due to their intricate alarm call system (Frederiksen & Slobodchikoff 2007, Slobodchikoff et al. 2009). They can create new 'words,' speak different 'dialects' in different colonies, and can even distinguish humans wearing different colored shirts moving at different speeds (Slobodchikoff et al. 2009). As prey animals, prairie dogs rely upon detailed warning calls to keep track of lurking predators. Their communication system is critical to each individual's survival.

The range of prairie dogs was very large prior to the 1800s. They inhabited the short and mixed grass prairies of Arizona, Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, and Wyoming (see Figure 1).

Before white American settlers began migrating westward, there were approximately 5 billion prairie dogs spread over the grasslands.⁶ These historical complexes were comprised of small and large prairie dog colonies, and re-establishing this distribution pattern would stabilize current populations and support the species' critical ecosystem functions (Kotliar et al. 2006).

Ecologists consider prairie dogs to be a keystone species in short and mixed grass prairie ecosystems (Kotliar et al. 2006, Long 2002, Graves 2001, Slobodchikoff et al. 2009). A keystone species is characterized by its significant, unique, and disproportionate impact on an ecosystem. Prairie dogs meet these criteria: they aerate the soils by digging, improve water retention, stimulate plant growth, clip vegetation, and create long and deep burrows that provide habitat for many prairie species. Large prairie dog colonies have much higher species biodiversity when compared to the surrounding prairie (Shipley & Reading 2006); over forty species of mammals, fifteen species of reptiles, ten species of amphibians, eighty species of plants, and ninety species of birds are significantly associated with prairie dog colonies (Graves 2001).

⁶ United States Department of Agriculture researchers have disputed historical prairie dog numbers and the species' ecological importance (Vermeire et al. 2004). However, Forrest refuted their arguments, which (in addition to noticeable mathematical errors) ignored historical populations of bison, long-term climatic patterns, and natural population fluctuations (2005).



Figure 1. Historical range (1800s) of black-tailed prairie dogs in North America. Source: Prairie Dog Coalition, 2009.

Prairie dog colonies are also home to many rare, imperiled species (Lomolino & Smith 2004). Prairie dogs are a very important prey source for many species, such as ferruginous hawks and swift foxes (*Vulpes velox*). Black-footed ferrets (*Mustela nigripes*) are an obligate species—they are completely dependent upon large prairie dog colonies for survival, as prairie dogs are their principal food source. Prairie dog burrows also provide shelter and nesting space for black-footed ferrets. Burrowing owls (*Athene cunicularia*) rely heavily upon prairie dog burrows for shelter and nesting space (Lantz et al. 2007, Lantz & Conway 2009, Restani et al. 2008). Mountain plovers (*Charadrius montanus*) prefer prairie dog habitat to the surrounding prairie (Tipton et al. 2008). These associated species' populations have plummeted as prairie dogs have vanished.

The prairie ecosystem and dozens of other species, including humans, benefit from the distinctive landscape of prairie dog colonies. While prairie dog ecosystem services have not been quantified economically, their presence provides notable benefits. Burrowing aerates the soil, mixing subsoil and topsoil layers. This activity also redistributes nutrients, often increasing vegetation productivity and protein content (Kotliar et al. 2006). The clipped vegetation of large colonies can act as a firebreak (Kotliar et al. 2006). In addition to these natural services, prairie dogs have advanced medical research of human gallbladder disease, since they often develop gallstones (Hoogland 2006). Prairie dogs are extraordinarily important to the prairie ecosystem—engineering a unique landscape, providing habitat and food for other species, cycling nutrients, improving water retention, and benefiting humans through these ecosystem

services and contributions to biological research. Despite their undeniable importance to prairie landscapes and fascinating communication system, these creatures are routinely mischaracterized and misunderstood (Miller et. al 2007).

Pushed to the Brink: The Persecution of Prairie Dogs in the American West

This keystone species has disappeared from much of its range.⁷ Ecologists now estimate that prairie dog colonies cover only one to two percent of their original extent (Fox-Parrish & Jurin 2008, Hoogland 1995). Prairie dogs' native grasslands are still rapidly disappearing (Licht 1997, Slobodchikoff et al. 2009).

Many factors have contributed to the striking decline of prairie dogs. Relentless extermination campaigns run by federal and state governments, habitat loss and fragmentation, recreational shooting, and devastating outbreaks of sylvatic plague have put enormous pressure on the species. Other than sylvatic plague, the principal threats are “anthropogenic and entirely manageable” (Lomolino et al. 2003). However, these anthropogenic threats are only manageable if entrenched public stereotypes are addressed and government policies at all levels shift to support preservation of this keystone species. Considering the long history of deadly prejudice leveraged against prairie dogs, this presents a major political challenge.

⁷ For example, they have been extirpated from the state of Arizona.

The effects and impact of competition between cattle and prairie dogs remain contested.⁸ Since prairie dogs consume grasses and forbs, the general, historical assumption was that they compete directly with cattle for forage. In 1902, a prominent biologist pronounced—with no explanation of his data—that 256 prairie dogs consume as much forage as one cow (Hoogland 1995, Slobodchikoff et al. 2009). (One prairie dog actually consumes about two pounds of forage per month (Miller et al. 2007).). However, prairie dogs did co-exist with 30 to 60 million bison before 1800 (Miller et al. 2007, Slobodchikoff et al. 2009) and colonies are often preferred pronghorn grazing grounds.

Prairie dogs also tend to occupy disturbed areas with large amounts of bare soil—areas that appear barren (Slobodchikoff et al. 2009). While prairie dogs prefer to colonize landscapes that provide high visibility, the general public, government officials, and ranchers have long assumed that prairie dogs are the cause, rather than the result, of barren landscapes. Thereafter, contemptuously regarded as vermin competing with cattle for valuable vegetation, countless colonies were poisoned by the U.S. Biological Survey in the early 1900s. Between 1916 and 1920, the federal government deployed an estimated \$143.65 million to poison prairie dogs (in 2009 dollars, Slobodchikoff et al. 2009).

⁸ It is possible that while prairie dogs reduce vegetation height, they improve the quality of forage. In effect, prairie dog presence is only a notable detriment to cattle yield when the land is over-grazed (Hoogland 1995, Wuerthner 1997, Slobodchikoff et al. 2009). In Colorado, one study found cattle utilize prairie dog towns in proportion to their availability (Guenther & Detling 2003).

The poisoning campaigns tapered off in the late 1930s, as most prairie dog complexes had been eradicated. However, poisoning remains a common management practice today. For example, the United States Forest Service poisoned nearly 100,000 acres of prairie dogs on national grasslands between 1985 and 1998, as part of their good-neighbor policy to ranchers (Johnsgaard 2005). Despite a significant price tag, this poisoning barely changes cattle productivity (as measured by weight gain, which determines market value) (Miller et al. 2007). Assuming twenty percent occupancy by prairie dogs, there is a cattle productivity gain of about \$2/acre, while the poison and labor costs about \$74/acre (Miller et al. 2007). Despite typically low reproduction rates, prairie dog population rebound after poisoning tends to increase eradication expenses over the long-term. In many urbanizing areas, poisoning or razing colonies still constitutes the primary removal method once land is zoned for development.

Historical habitat loss stemmed primarily from the conversion of prairie to agricultural land and ranches. Since the late 1800s, one-third of prairie dog habitat has been converted to cropland (Proctor et al. 2006, Forest Guardians et al. 2007). Large expanses of grasslands have become rare, reflecting this long history of replacing native landscapes at the behest of agricultural and ranching interests (Johnsgaard 2005). These native grasslands provide undervalued ecosystem services, as they recharge aquifers, mix soils, cycle nutrients, control erosion, sequester carbon and methane, and provide climate control (Slobodchikoff et al. 2009). Prairie dogs provide their own array of ecological

benefits within grasslands, but their pivotal role has been crippled. They are functionally extinct (Wuerthner 1997, Miller et al. 2007).

In addition to poisoning and habitat loss, the contemporary threat of recreational shooting devastates prairie dog colonies. Combined with the immense decline in prairie dog numbers, as well as their slow reproductive rate, the annual amount of prairie dog shooting is staggering (Slobodchikoff et al. 2009). These highly social animals are unable to carry out their daily grazing and social activities with even light shooting. Shooting increases in the spring, when females are nursing young pups. The skewed impact on lactating females greatly reduces the survivorship of the next generation, as well as successful pregnancies during the subsequent breeding season (Pauli & Buskirk 2007b, Slobodchikoff et al. 2009). Other species, such as burrowing owls, may also be accidentally shot during their movements within the colony. Finally, unregulated shooting often results in lead entering the prairie ecosystem, which can cause lead poisoning in burrowing owls, ferruginous hawks, golden eagles, and the black-footed ferret (Pauli & Buskirk 2007a, Slobodchikoff et al. 2009).

Sylvatic plague is another deadly and recent threat to the long-term survival of prairie dogs. Introduced from Asia around 1900, sylvatic plague generally kills all prairie dogs in a colony within a few days of infection (Collinge et al. 2005, Antolin et al. 2006, Pauli et al. 2006). Although prairie dogs have not been linked to infecting humans with this plague, the public has a consistent fear of prairie dogs harboring and spreading this flea-borne disease (Johnsgaard 2005, Slobodchikoff et al. 2009). This fear is unfounded.

First, incidences of plague in the United States of America are exceedingly rare. Second, the disease can be easily treated with early detection. Finally, people are more likely to interact with prairie dogs in an urban or suburban setting, and these colonies may be even less likely to suffer from plague outbreaks due to their relatively acute isolation (Lomolino et al. 2003, Magle et al. 2009). No plague events have been detected in the Denver metropolitan area within the last five years (Magle & Crooks 2009). Thus, urban residents who refrain from interactions with dead prairie dogs have very little reason to fear contracting the plague from this species. Sylvatic plague presents a severe threat to prairie dogs' long-term survival, but should present no more than a minor health caution to urban residents.

The final contemporary threat to prairie dogs' long-term survival is the sprawling growth of cities and suburbs, which has reduced and fragmented remaining grasslands. Flat land, which prairie dogs preferentially inhabit, is the ideal location for sprawling big-box stores and housing developments. This rapid land use conversion has left many isolated and small colonies, which are more vulnerable to localized extinctions (Magle & Crooks 2009, Wuerthner 1997). Since successfully migrating prairie dogs are probably few and far between in an urban landscape, genetic drift may also become a problem for a colony's long-term survival. Finally, species richness on prairie dog colonies is associated with the characteristics of the surrounding landscape (Lomolino & Smith 2003). When a colony is stuck in a sea of concrete, it struggles to sustain a diverse habitat patch.

Given this immense loss of habitat and population, restoration is critical to the species' recovery. In addition to the potential for restoration at the local metropolitan scale, significant expanses of grasslands could be restored as viable habitat. For example, National Grasslands encompass approximately 1.5 million hectares, much of which is potential habitat but very little of which is occupied by prairie dogs (Sidle et al. 2001). Restoration can also be facilitated via relocation, which is increasingly a preferred alternative to lethal management (Roe and Roe 2003). Unfortunately, relocated prairie dogs often have very low survival rates.

There are feasible ways to encourage prairie dog expansion into suitable habitat. For example, controlled burns and brush removal facilitates colony expansion (Milne-Laux & Sweitzer 2006). Soil, vegetation, slope, previous use of the relocation site by prairie dogs, proximity of the site to existing prairie dogs, and natural dispersal barriers are important factors to consider when evaluating the suitability of a relocation site (Roe & Roe 2003). However, relocation does not tackle the root problem of human-wildlife conflict.

In 2009, prairie dogs were once again denied listing as a Threatened or Endangered species, with a Record of Decision coming from the United States Fish and Wildlife Service (USFWS). Previously, after a 1998 petition, the USFWS determined that the prairie dog merited listing, but existing funds precluded protection. In 2004, the USFWS removed the prairie dog as a candidate species. The continued lack of protections at the local, state, and federal level provide little indication that stable

populations will be maintained. Protecting and restoring prairie dog populations would provide critical stability for the short and mixed grass prairie ecosystem. Until then, prairie dogs and associated species will struggle to survive.

Colorado's Prairie Dogs

There has been a decline in prairie dog populations at all scales: national, regional, state-wide, and local. Historically, the state of Colorado had three to seven million acres occupied by prairie dogs. (Forest Guardians et al. 2007). Between 1903 and 1912, Colorado exterminated over 90% of the state's prairie dogs; then, between 1912 and 1923, an additional estimated 31 million prairie dogs were killed (Wuerthner 1997). Colorado reflects the national pattern of an extraordinary decline in prairie dog population (around ninety-nine percent).

State policies remain skewed towards prairie dog eradication. The Colorado Department of Agriculture designates prairie dogs as destructive rodent pests. County-level policies are accordingly hostile to the prairie dogs:

In 2005, Prowers County, Colorado—home to some of the largest concentrations of prairie dogs in the state—began financially subsidizing landowners for poisoning prairie dogs on their private land. Baca County provides grants to private landowners who request assistance in poisoning prairie dogs on their property. [...] In 2006, the Logan County Commissioner authorized a rebate program that covers the private use of the poisons Rozol and Kaput on prairie dogs. [...] Yuma County officials assist willing landowners in poisoning prairie dogs on their property. Broomfield County kills prairie dogs annually in residential buffer zones and on private land. (Forest Guardians et al. 2007, 117)

Colorado has a spring shooting moratorium, but it does not apply to private and many state lands (WildEarth Guardians 2009). The state believes that populations exceed target levels and therefore do not merit significant conservation efforts (WildEarth Guardians 2009).

However, current estimates of occupied colony area for Colorado remain elusive. An aerial survey estimate, with stratified sampling at the county scale, yielded an estimate of approximately 250,000 hectares (630,000 acres) (White et al. 2005a). These data suggest that prairie dogs only occupy two percent of their potential habitat (White et al. 2005a). However, the protocols used to collect that data substantially inflated colony areas (Miller et al. 2005). The Colorado Division of Wildlife authors argued that these critiques were biased and skewed in their sampling methodology (White et al. 2005b); a subsequent estimate of Colorado's occupied colony acreage performed an accuracy assessment and recorded an increase of 29% in occupied acreage (Odell et al. 2008). However, conservation organizations have argued that these estimates are once again severely inflated (Forest Guardians et al. 2007).

Within this statewide pattern of decline, Denver's prairie dog colonies are susceptible to loss from further urban development (Magle & Crooks 2007). Important factors in local extirpations include systematic lack of protections and colony isolation (Magle & Crooks 2009). Between 2002 and 2007, Magle & Crooks (2009) documented 18 colonization and 28 extinction events in Denver and its southern suburbs. In 2007, Denver had approximately 907 acres of occupied prairie dog colonies. There is a very

wide range in colony size, from .04 acres to 101.1 acres. While the mean colony area was 12.1 acres, the median colony area was 5.8 acres. Although the occupied colony areas fluctuate over time, Denver's colonies are consistently grouped on the less-densely settled urban fringe, near suburban developments in Hampden, Stapleton, Denver International Airport, and Lakewood (Figure 2). However, the future of these colonies depends upon minimizing human-wildlife conflict and conserving prairie habitat spaces.

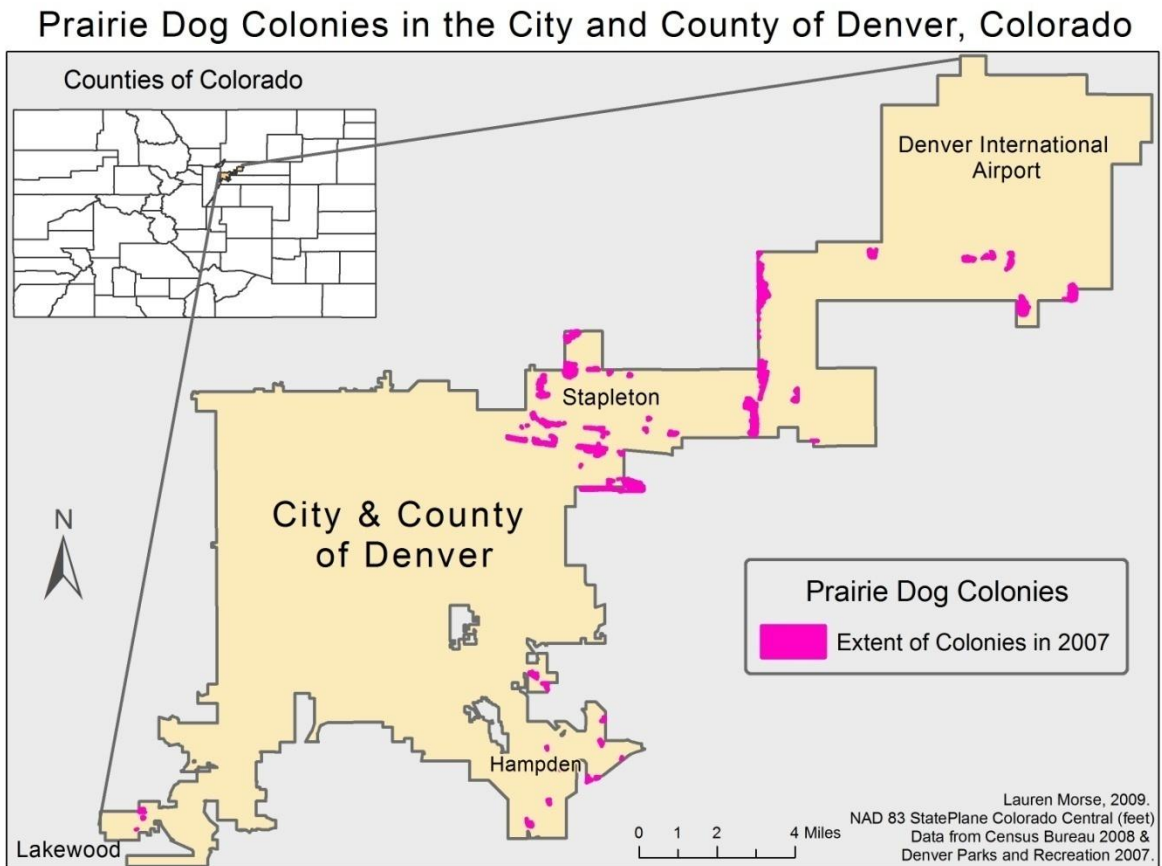


Figure 2. Map of known prairie dog colonies in Denver, Colorado, 2007. Data Source: Denver Parks & Recreation.

Literature Review

The viability of urban wildlife depends upon interacting ecological and social factors in a specific metropolitan environment, as it would be short-sighted to ignore one aspect in favor of another. Urban open space may be physically suitable for wildlife populations; however, if the neighborhood does not support the presence of various fauna, removal through lethal methods or habitat alteration is likely. Therefore, this section will provide an overview of critical urban wildlife themes: the distribution of urban habitat and the ability of remote sensing to identify such habitats; the interactions between animals, environments, and humans within a complex urban landscape; and finally, how these ecological and social variables play out in the lives of prairie dogs and people.

Urban Habitat Identification

Urban wildlife viability depends on the quantity and quality of available physical space. It is difficult to maintain sufficient native ecosystem space within dynamic, fragmented, and valuable metropolitan land. In isolated urban patches, there is a real danger of genetic drift (Soule 2008, Natuhara 2007). Even if some patches are accessible to dispersing individuals, they may become a population sink rather than a robust source

of intraspecific diversity.⁹ Regional and connections must be fostered to avoid isolation (Magle & Crooks 2009); otherwise, translocation becomes necessary to sustain isolated urban populations (Soule 2008). Fortunately, cities are connected to rural areas by natural and man-made corridors (Hough 2004). Highways facilitate human movement, while greenways facilitate animal dispersal.

Although significant ecological hurdles limit viable space for urban wildlife populations, scientists believe that habitat remnants can conserve biodiversity while meeting open space needs (Markovchick-Nicholls et al. 2008). There is great potential for local species diversity if urban habitat patches vary greatly in vegetation community structure (Hough 2004). Despite size constraints, urban green spaces can be tailored to maintain ecosystem services, such as nutrient cycling and water filtration (James et al. 2009). As urban open space provides many utilitarian benefits for residents and wildlife, it is critical to be able to determine the distribution and characteristics of such space at multiple scales.

Remote sensing has great potential to aid urban conservation efforts through habitat identification and classification. Image analysis can be both cost and time effective while producing acceptably accurate land cover information, particularly when

⁹ Island biogeography is particularly informative in understanding ecosystem processes of isolated urban fragments. The area effect states that the rate of species extinction in an isolated patch of habitat is inversely related to its size. The distance effect notes that the relation between isolation and movement frequency is inverse. Dispersal from other populations is an important safeguard against local inbreeding or other random catastrophe. (Wolch et al. 1995, Soule 2008).

modeled with additional information that can be included in a GIS (Geographical Information Systems), such as habitat patch size (Wiens et al. 2009). Habitat monitoring and detection procedures can be applied to urban environments, where many native species utilize fragmented patches within a highly heterogeneous landscape. Remotely-sensed images are able to distill the complexity of urban land into three broad—and potentially overlapping—land covers: built, cultivated, and natural, which can be leveraged for urban habitat identification and targeted conservation efforts (Potere et al. 2009). After successful identification at the metropolitan scale, these areas can be restored and protected as urban wildlife refuges.

However, urban habitat detection and identification is challenging. First, heterogeneous and dynamic land cover requires extremely fine spatial and temporal resolution. Unfortunately, there is usually a trade-off between spatial and temporal resolution—it is not possible to maximize both (Potere et al. 2009). In addition, classifying vegetation is also difficult due to the number of mixed pixels.¹⁰ Shadowing presents another obstacle; most urban areas contain high amounts of shade, which mute land cover detail by dampening the signal the sensor records (Nichol & Wong 2007).

¹⁰ A mixed pixel occurs when the sensor records at least distinct two land cover types in one pixel and thus the pixel's resulting spectrum measures a weighted sum of the reflectance of each material (Assal and Lockwood 2007). In contrast, a "pure pixel" theoretically encompasses one and only one land cover type and the recorded spectrum therefore measures only one land cover type captured in the satellite's field of view (e.g., water, bare soil). Spectral mixing is unavoidable in prairie dog colony detection, as they usually contain differing proportions of bare soil and vegetation.

Finally, urban landscape composition varies temporally and regionally. Habitat detection and associated classification algorithms must be sensitive to these site differences.

Spectral mixture analysis provides a useful methodology to extract critical sub-pixel information in urban scenes (Nichol & Wong 2007, Yunhao et al. 2006). This procedure allows the remote sensing scientist to analyze or model how the proportions of land cover are distributed in the metropolitan setting. Spectral mixture analysis, or spectral unmixing, obtains additional land cover detail (which is not present in the aggregated spectra of a single pixel) by effectively deconstructing a pixel into its proportional material components. For example, a pixel's spectrum may be deconstructed in addition to some percentage of shade and green vegetation. Each pixel is modeled in terms of the fractional abundance of materials present, which is particularly useful in distilling information from complex urban environments.

An additional difficulty in habitat classification for urban environments is that traditional supervised or unsupervised algorithms assign each pixel to only one class and thus may be inaccurate representations of complex land cover composition in urban areas (Tooke et al. 2009). Yet another challenge in urban habitat identification arises from the typically rapid land cover change in urban areas. Despite these challenges, the goal of this research is to investigate native habitat patches in conjunction with the surrounding human environment, as the long-term viability of urban wildlife depends on mitigating conflict (Savard et al. 2000, Hough 2004, Messmer 2000).

Urban Ecology

While we often think of the densest flows of nutrients, elements, and energies to be those of tropical rainforests and diverse savannas, they are certainly at their most complex in urban environments. City streets, gardens, golf courses, kitchen sinks, and garages are all teeming with life, connected and regulated through systems of power and fixed through investments of capital...A political ecology of the city can expand [...] to explain how these urban ecologies are produced and why these ecological networks look the way they do [while being admittedly] agnostic to whether or not a forested 'wilderness' or a suburb is more natural... (Robbins 2004, 216)

Urban ecology has evolved significantly since its inception in the 1920s. Originally, riding the wave of Darwinian thinking in the social sciences, urban ecology envisioned the city as an organism that evolved and functioned in a predictable way. That perspective has since waned. Contemporary urban ecology aims to incorporate humans into ecological studies, a long-neglected integration despite the powerful, human-induced ecological changes across spatial and temporal scales, which are particularly evident within and around growing urban areas (Alberti et al. 2003). Urban ecology attempts to foster a new synthesis among social sciences, natural sciences, and policy-making in order to start exploring the intersection of physical and human environments within heterogeneous urban settings (Alberti et al. 2003, Collins et al. 2000, Goode 1998, Melosi 2003).

Urban ecology thus far consists of an amalgamation of case studies, includes practitioners from many fields (e.g., ecology, landscape planning, conservation biology), and yet contains significant thematic commonalities. Urban ecologists often describe this field as the analytical and theoretical framework that can mitigate the ecological damage

wrought by urban development and the estrangement of people from local environments (Bryant 2006, Collins et al. 2000, Edgar 2007, Ricketts & Imhoff 2003, Wittig 1998). With broad growth trends indicating a global loss of biodiversity amidst overwhelming human sprawl, many urban ecology works emphasize the need for conservation planning tailored to attract local support (Edgar 2007, Elliot 2006, Goode 1998, Talen & Brody 2005). Many researchers also recognize that to truly support urban wildlife—which is imperative due to the rate of urban population growth and suburban sprawl—regional connections must be fostered through greenways, corridors, and the preservation of open rural space (Ahern 2004, Bryant 2006). Ultimately, urban areas should create accommodating social and physical spaces for wildlife.

Urban Wildlife

The nascent body of urban wildlife studies has thus far focused on cities in developed nations, on birds and mammals, and on conservation interests. Studies integrating multiple scales are rare; comparative studies appear to be non-existent; human perceptions of urban wildlife are seldom explored. There is neither an integrative body of thought nor a grand theory that inspires scientists to engage with urban wildlife themes and case studies. Wolch et al. (1995) proposed the outlines of a trans-species urban theory integrating wildlife into urban ecology, but this seminal work has not been substantively expanded. In addition, multi-scale analysis is needed to improve

understandings of local and regional wildlife populations, while also accounting for socio-economic phenomena at the appropriate scales.

Urban wildlife studies examine human-wildlife interactions in metropolitan settings; these interactions are often contentious. Metropolitan environments largely remain hostile to most vertebrate species; it is especially difficult for mammals to thrive in an urban structure that limits their movement (Garden et al. 2006). Nonetheless, even lacking corridors and habitat, shadow animal populations manage to survive in the city (Wolch 2002, Alberti et al. 2003). Recognizing the benefits of urban wildlife, some communities are working to incorporate wildlife into their built environments (Wolch 2006). Since urban growth is anticipated to be highest in temperate and tropical areas containing high levels of biodiversity, community-based efforts, combined with regional policies, are critical in mitigating the impacts of rapid development on remaining wildlife (Garden et al. 2006, Ricketts & Imhoff 2003). The success of these efforts hinges on eliminating the pervasive separation of nature from civilization and, by extension, minimizing human-wildlife conflicts.

Americans have romanticized wilderness as pristine nature since the Romantic period (Cronon 1995). Cronon explains the problem with this national ethic:

Idealizing a distant wilderness too often means not idealizing the environment in which we actually we live, the landscape that for better or worse we call home [...] Indeed, my principal objection to wilderness is that it may teach us to be dismissive or even contemptuous of such humble places and experiences. (1995, 21-22)

Wildlife is also relegated to this idealized and remote wilderness. There is no place for wild animals to exist peacefully in cities; urbanization constricts their existence (Wolch et al. 1995). Nature and wildlife are typically envisioned as part of a distant (and shrinking) wilderness rather than local landscapes. When wildlife enters into the prosaic spaces where humans live and work, people become disconcerted. Elk may be quite the majestic sight in Rocky Mountain National Park, but a menace if they habitually wander into nearby towns. Wildlife becomes perceived as over-abundant pests which threaten the neighborhood safety, forage in local vegetation, and carry diseases (Messmer 2000). Much local wildlife is perceived as intrusive; repeated trespass across the civilization-wilderness boundary makes animals a nuisance, a threat to our civilized and cultivated world.

This fissure between the perception of wilderness and the actual impacts of urban wildlife leads to very public conflicts (Wolch et al. 1995, Messmer 2000). Human-wildlife conflicts present quite the challenge because they are often caused by human behavior, which is difficult to change without extensive education or enforced regulations (Savard et al. 2000). Over sixty percent of urban households experience conflict with wildlife and try to manage local species (Messmer 2000). Unfortunately, most urban residents do not know how to behave when thrust into unfamiliar proximity with native creatures. Usually, repeated animal intrusions become increasingly threatening and the offending animal is killed in the interest of public safety. The conflict may be real or perceived (Messmer 2000); either way, the stakeholder *perceives it as real*. Each year,

United States government agents kill an estimated 90,000 ‘problem’ coyotes—a species that is increasingly roaming through suburbs (Stark 2009). In the summer of 2009, the Colorado Division of Wildlife killed 25 ‘problem’ bears, a reflection of increased in-town foraging (Finley 2009). Finally, Colorado’s ranchers have a long-standing conflict with elk competing for grazing land that has resulted in illegal killings (Buchanan 2008). Even beloved birds of prey may carry away unwary housecats and lapdogs. While all of these wild species may be perceived as charismatic—even iconic—from a distance, their local presence produces intense conflict over concerns related to human safety and economic losses.

The treacherous dichotomy between wilderness and civilization is even more evident for native animals that have been designated as urban pests. (A pest designation emerges from the widespread perception of harms; it is definitely possible that a pest designation perpetuates the association of harms and obscures benefits deriving from a particular species or ecosystem.) With a pest species, direct management such as culling or translocation is generally preferred. Pest species are purposefully excluded from the local landscape; however, the ostracized animals may then migrate to the open space, find new marginal habitat, adapt to the altered landscape, or perish for lack of habitat (Wolch et al. 1995).

There are some fortunate urban fauna that are perceived as an amenity (Pickett et al. 2008). These animals are unfailingly charismatic; the peregrine falcon is one species that has attracted positive attention to urban conservation efforts (Savard et al. 2000). In

marked contrast, decidedly uncharismatic animals often become a source of political grievance. For example, urban geese populations have exploded, as the species has successfully adapted to urban and suburban habitats (Savard et al. 2000). The resulting grazing and defecation ruins local parks and other manicured areas. People vigilantly defend their public and private property from such ‘overabundant pests’ that ruin landscaping and cause disturbance—even though humans create the ideal habitat for geese in the form of fertilized lawns, parks, and golf courses often accompanied by artificial bodies of water. These edge habitats, created through urbanization and suburbanization, are attributable to human design (Wolch et al. 1995).

Despite such conflicts, urban wildlife provides myriad benefits for urban residents and visitors. A majority of Americans engage in non-consumptive wildlife recreation each year, select wildlife species are perceived as an amenity by urban homebuyers, and supporting urban wildlife fits in perfectly with the rise in sustainability ethos (Wolch et al. 1995, Wolch 2007). Urban wildlife species may promote a city’s identity; for example, salmon are designated as a critical species to the entire metropolitan area of Seattle (Wolch 2002). The fish attract tourists, but also is a source of urban pride which successfully promotes local habitat restoration (Wolch 2002). Urban wildlife creates an opportunity for ecological education and a tangible connection to local environments. Natural open spaces also lower stress and reduce crime in nearby urban areas (James et al. 2009).

Professional urban wildlife management is needed at neighborhood, metropolitan, and regional scales. This field is loosely defined as the application of ecological knowledge to balance wildlife populations with human needs (Messmer 2000). Wildlife needs are primarily bio-physical¹¹; they need open space and stable corridors (Hough 2004). Urban wildlife should be managed to minimize conflict and support diversity, for a decline in biodiversity may lead to serious and sustained declines in productivity (Robbins 2004). Conversely, human needs are rooted in socio-economic dynamics, historical prejudices, and dissociative constructions of nature (Cronon 1995). These environmental constructions are embedded in stories of past ecologies and inextricably tied to political control of the environment, whether urban or rural (Robbins 2004).

Urban Prairie Dog Studies

There is limited ecological research on urban prairie dog colonies (see Figure 3). Magle et al. examined prairie dog behaviors in the Denver metropolitan area, concluding that urban prairie dogs are less sensitive to human intrusion than their rural counterparts (2005) but have similar effects on vegetation (Magle & Crooks 2007). Although isolated urban colonies are vulnerable to genetic drift, these colonies can support genetic variability by improving flows between larger and smaller colonies (Trudeau et al. 2004).

¹¹ Minimizing conflict involves not only changing the way humans view and interact with urban wildlife, but understanding that wildlife may get stuck within built areas of an urban environment (e.g., a rattlesnake in a household's pool) and would require professional assistance in finding its way back to natural spaces, whether urban or rural.

In Denver, colony connectivity was the greatest predictor of current prairie dog occupancy, while fragment size and the amount of graminoid¹² cover were also significant factors (Magle & Crooks 2009, Magle et al. 2009).



Figure 3. Urban prairie dog colony in Denver, Colorado. Photo by Lauren Morse, August 2009.

A few works have addressed human perceptions of prairie dogs. Urban residents tend to display more positive attitudes towards prairie dogs than rural residents (Reading et al. 1999). A study of secondary school students found general apathy despite the visibility of local prairie dogs (Fox-Parrish & Jurin 2008). Indeed, students described prairie dogs as nuisances, bad for ranchers, and disease-bearing. These myths and

¹² Graminoids include grasses and sedges.

stereotypes about prairie dogs are perpetuated by friends, family, newspaper articles, and a long history of ranching in western United States (Reading et al. 1999). Natural resource personnel working locally tended to have less knowledge and poorer attitudes in regards to prairie dogs than those working regionally or nationally (Reading et al. 2006). Another attitudinal survey found that those with direct experience with prairie dogs also held more negative views of the species; the authors proposed that wildlife managers should educate the public on the keystone role of the prairie dog, as the idea of these rodents as a critical species has not been embraced by the public (Lamb & Cline 2003).

One study utilized an attitudinal survey to explore attitudes towards prairie dogs in Fort Collins, Colorado (Zinn & Andelt 1999). The study concluded that residential proximity to prairie dog colonies significantly increased both knowledge of the species and an acceptance of controlling their population through poisoning (Zinn & Andelt 1999). The authors discovered that residents separated from a colony by 1 house or more reported conflict at much lower rates than residents living adjacent to a colony (Zinn & Andelt 1999). On the other hand, a survey conducted in Montana found that knowledge was not correlated with values and attitudes towards prairie dogs (Reading et al. 1999). There are conflicting results across temporal and spatial scales in these studies. Thus, while informative sources on urban prairie dogs exist, there is a clear need to integrate the ecological and social aspects of urban prairie dog colonies to explore spatial patterns in Denver.

Study Area, Data, & Methods

This case study provides the opportunity to examine the ecological and social components of urban prairie dog viability in Denver, Colorado. The central city, defined as the municipal boundary, was chosen as the scale of analysis for several reasons: there are numerous prairie dog colonies remaining in Denver; many are located near residences on the urban fringe; finally, these urban colonies provide a diversity of sizes, locations, age, and social setting. For example, there is a colony, of around 25 acres, located on the edge of Stapleton, a new urbanist development dominated by white middle class residents and replete with manicured green spaces. There is also a colony—demarcated with barbed wire—near Lakewood adjacent to multiple apartment buildings (see Figure 3).

The combination of both ecological and social measures provides more comprehensive insight into the long-term viability of urban prairie dogs in Denver. The dynamic ecological and social landscapes of the metropolis were thus by integrating two analytical methods: remote sensing and statistics. First, remote sensing facilitated the identification of potential prairie dog habitat in the metropolitan area. Open prairie space (with spectral characteristics, slope, and size similar to those of known urban prairie dog colonies) was utilized as a proxy for potential colony locations. The remote sensing methods targeted the remaining native prairie spaces in Denver, establishing open prairie locations in order to subsequently examine social environments.

The second component of the mixed methods employed statistics to analyze urban residents' demographics, location, specific ecological knowledge, and attitudes regarding prairie dogs. The attitudinal survey targeted two groups: those residents who live near prairie dog colonies and those residents who live near potential colonies. The former group, on average, has more interactions with prairie dogs and thus their attitudes may have been significantly influenced by these frequent encounters (Reading et al. 1999). On the whole, most of the latter group is assumed to experience infrequent interactions with prairie dogs; yet, they may be living next to a potential relocation or expansion site for prairie dogs.

Remote Sensing & Urban Habitat Identification

To discern whether and where viable open habitat still exists in the City & County of Denver, two questions must be answered: What land cover proportions (specifically, soil and senesced grasses) are found in existing urban prairie dog colonies? What areas share these traits and thus can be classified as viable potential colony habitat?

Prairie dogs inhabit short and mixed grass prairie as well as moderately barren land. They clear their burrow mounds of vegetation and clip nearby vegetation. Their habitat is not vertically complex, so shade is not expected to be a significant spectral component (see Figure 4). As a result, soil and non-photosynthetic vegetation (NPV¹³)

¹³ NPV refers to dried-out, or senesced, vegetation—in this environment, primarily senesced grasses. This land cover component has a different signature from green vegetation, which is photosynthetically active.

spectra are the primary contributors to their habitat's spectral signature (Assal & Lockwood 2007). The difficulty in classifying prairie dog habitat occurs because colonies can be characterized by a range of compositions, from dominant soil cover to dominant NPV cover. Prairie dogs do not change the vegetation of their colony in a uniform way, so spectral mixing and habitat variability is a problem even in rural colony detection (Assal & Lockwood 2007). However, large rural colonies have been identified as a distinct patch in grassland land cover due to the increase in exposed soil and the low height of vegetation on colonies (Assal & Lockwood 2007).



Figure 4. Prairie dog burrow entrance. Photo by Lauren Morse, May 2009.

Furthermore, native grasses are expected to be senesced in late August, when the Landsat ETM+ scene was collected.

A Landsat ETM+ (Enhanced Thematic Mapper Plus) image was mosaicked from two August 2002 scenes and geo-registered to the NAD 83 UTM Zone 13N projection. However, the mosaicked Landsat ETM+ image extends beyond Denver's political boundary, as do a few of the recorded prairie dog colonies (see Figure 5). While the prairie dog colonies within the city's jurisdiction are the primary focus of this research, the entire image was spectrally unmixed and classified.

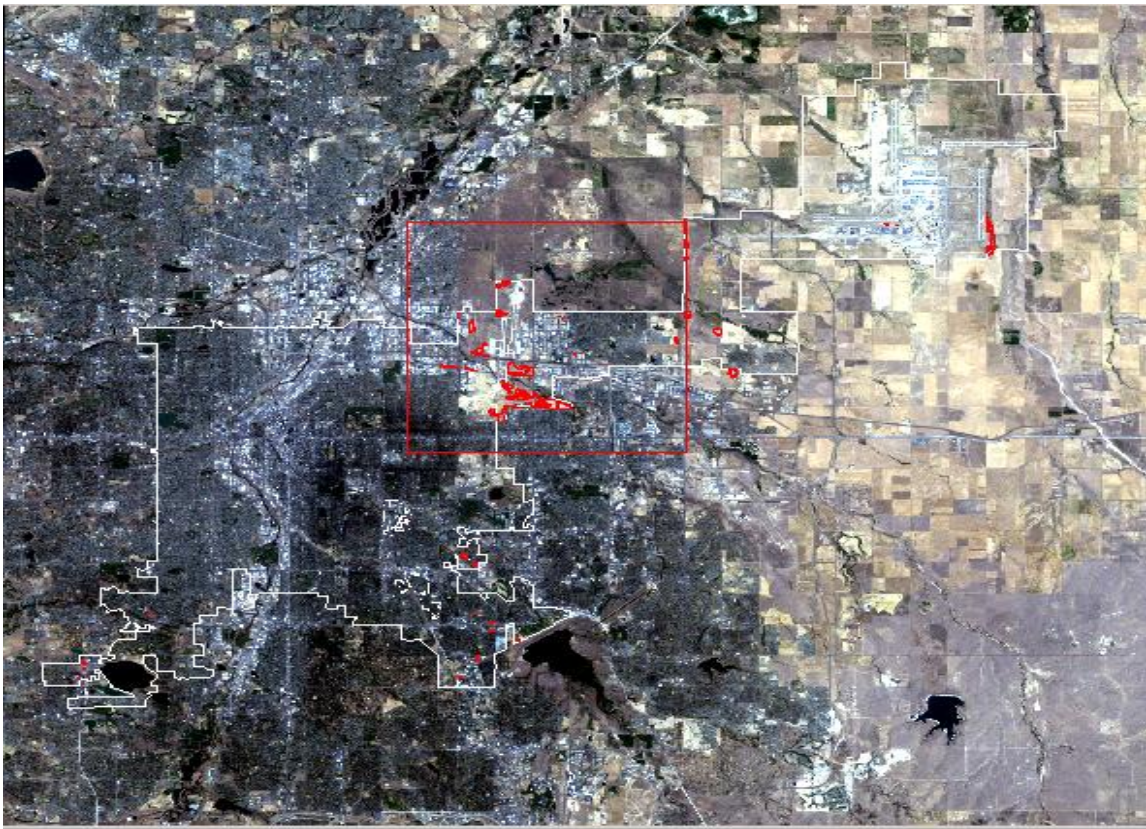


Figure 5. City and County of Denver, Colorado from an August 2002 Landsat ETM+ mosaicked image. Displayed in true color (R is Band 3, G is Band 2, B is Band 1.) The boundary for the City & County of Denver is shown in white; prairie dog colonies in 2002 are outlined in red. The red square was an area of interest which can be seen after spectral mixture analysis was performed in Figure 9.

Due to the heterogeneity of metropolitan areas, I chose to employ spectral mixture analysis before habitat classification, focusing primarily on the relative composition of NPV, green vegetation, and soil associated with Denver's existing prairie dog colonies. The model had four endmembers: NPV, green vegetation, soil, and shade. Each endmember was created from a single pixel, selected from within the Landsat ETM+ scene, which typified a pure spectrum of that surface (see Figure 6). The model was constrained to pixels containing less than 50% shade because colony habitat will have low shade fractions.

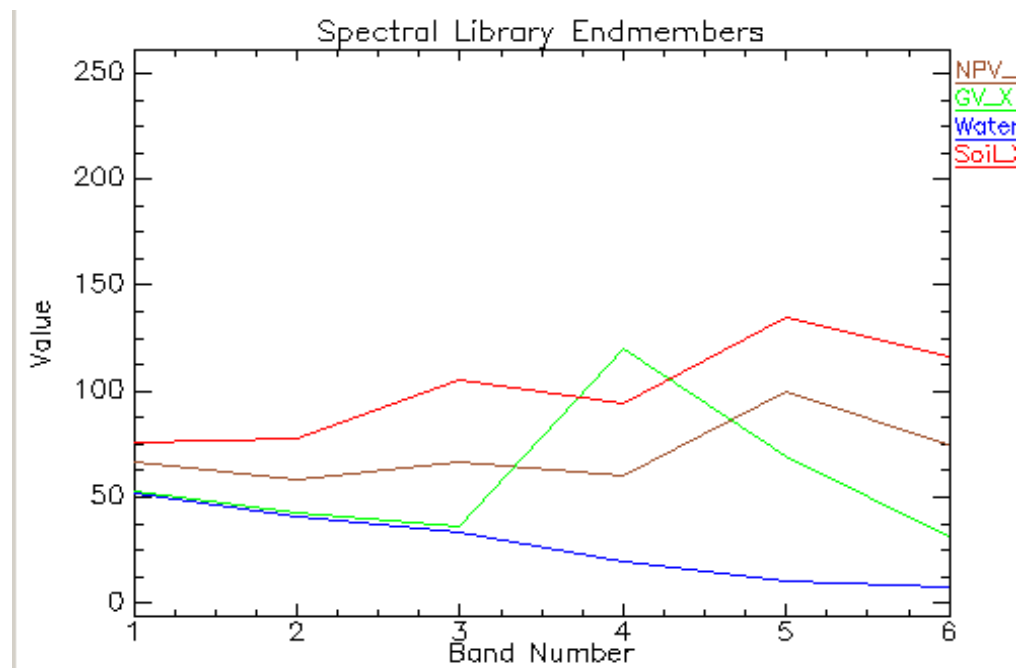


Figure 6. Endmember spectra used to in spectral mixture analysis, selected from the Landsat ETM+ image.

After the spectral mixture analysis, shade normalization was performed to more accurately reflect the habitat composition by removing the impact of shade on recorded pixels. Next, I imported a polygon shapefile delineating prairie dog colonies in 2002 and assessed the mean, minimum and maximum fraction of each material component derived from the spectral mixture analysis. Then, using the colony boundaries as a guide, I created and merged regions of interest within known prairie dog habitat. These regions of interest were drawn from known colonies dispersed across the scene. The selected pixels (545 in total) provided the basis for a supervised classification.¹⁴

I subsequently utilized a supervised Mahalanobis distance classification to classify all modeled land cover into two categories: existing/potential prairie dog habitat and non-habitat. Since prairie dog occupancy is also predicted by patch size of suitable habitat and slope, two additional GIS layers were incorporated. A 10 meter Digital Elevation Model (DEM) was transformed using the Nearest Neighbor algorithm and slope was then calculated for the resulting 30 meter pixels. The study area of Denver is generally flat; most areas had less than 10% slope. Areas classified as potential habitat which overlapped with areas of high slope were not considered in the selection of potential colonies. Finally, only areas greater than one acre were retained as potential

¹⁴ A supervised classification relies upon the user definition of typical class values to define typical land cover classes on the image; these inputs are used to ‘train’ the computer algorithm.

habitat (see Figure 7). This classification provided the sampling frame that would target two populations: residents near existing colonies and residents near potential colonies.

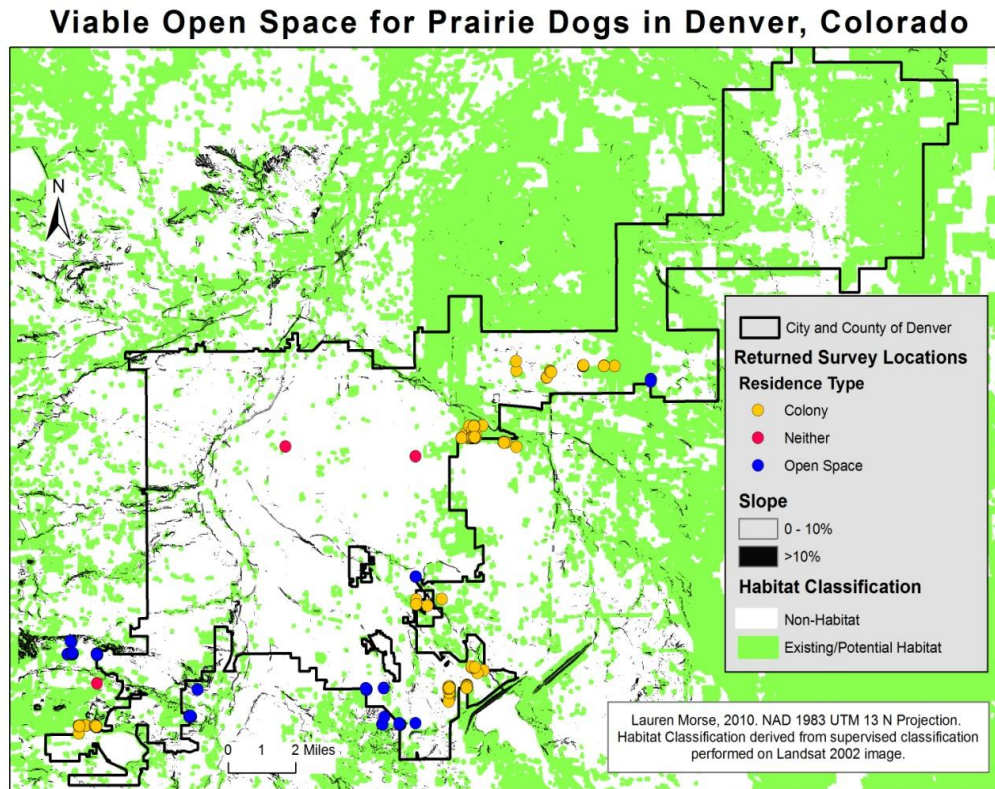


Figure 7. Map of existing/potential habitat and non-habitat areas in Denver derived from a supervised classification and the application of GIS information.

Statistical Methods & Perceptions of Wildlife

The next step in this research involved assessing the demographics, location, knowledge and attitudes of urban residents. A knowledge and attitudinal survey was administered to communities living near existing prairie dog colonies and potential prairie dog colonies in the City & County of Denver. All surveys began with brief section to elicit basic demographic information (e.g., age, gender, length of residence) and approximate residential location (i.e., the nearest street intersection) (see Appendix A). The next section included nine multiple choice questions about the resident's proximity to prairie dogs, knowledge of basic species traits, and knowledge of prairie dogs' interactions with other prairie species (including humans). Questions were asked regarding prairie dogs' keystone species role, association with black-footed ferrets, severe population decline, impact on ranching, association with the plague, and communication abilities. These multiple choice questions aimed to assess a respondents' general knowledge of prairie dogs, particularly in regard to myths and stereotypes associated with this species.

All survey items appeared in a standardized order. The sole exception was that half of the surveys included an educational component after the knowledge section, where the correct answers and short explanatory paragraphs were provided. The survey concluded with an attitudinal section comprised of ten statements employing a five-point

Likert scale¹⁵ along with a No Opinion option. This section was concerned with respondents' viewpoints on lethal management of prairie dogs, protections for urban prairie dogs, protections for local prairie spaces, the presence of hawks and eagles, the presence of local prairie dogs, and the development of remaining prairie landscapes. This section also included statements about the threat of prairie dogs to human health and livelihoods (i.e., ranching) in order to assess how these concerns were distributed across an urban population. Most of the attitudinal statements specifically referred to Denver prairie or Denver communities.

I distributed 1,017 knowledge and attitudinal surveys to 11 residential areas in August 2009 (see Figure 8). Six surveyed areas were near existing prairie dog colonies, and five surveyed areas were near potential colonies (509 surveys and 508 surveys distributed, respectively). The two study populations were mutually exclusive. The survey sampled residences clustered within 0.50 mile of an existing colony or a potential colony; both categories were clustered on the fringes of the city boundary. For existing colony sites, prairie dog colonies had been present since at least 1999. These survey areas were selected because the communities were accessible for survey delivery (e.g., not a gated community). The sampled areas included a mix of housing, such as low-density single-family housing and multi-story apartments.

¹⁵ Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree.

Survey Response Rate by Neighborhood Type in Denver, Colorado

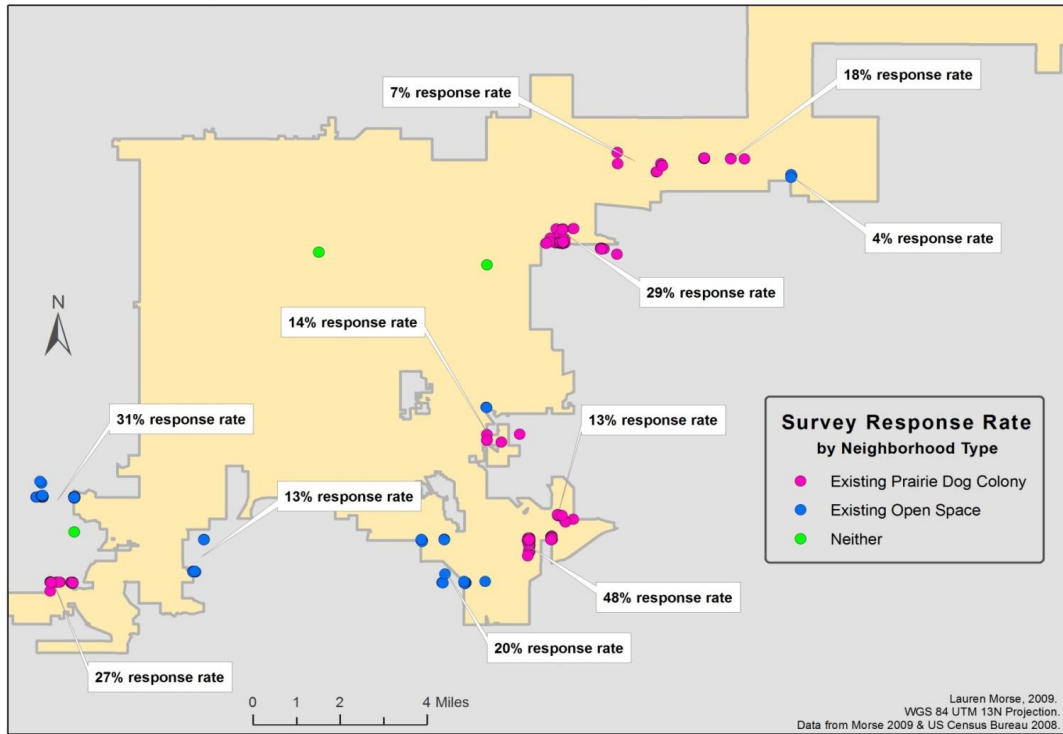


Figure 8. Map of survey response rate by neighborhood type in Denver, 2009.

Categorical analysis was used to compare nominal and ordinal variables (e.g., gender, knowledge categories) to ordinal responses (e.g., attitudes). After comparing gender, knowledge, residence type, and educational information to each attitudinal statement, I disaggregated the data into two subsets: respondents near existing colonies and respondents near potential colonies. The attitudinal statements were again analyzed in relation to the major variables of interest: gender, knowledge levels, and educational information.

Then, I applied factor analysis, a multivariate data reduction technique which captures and summarizes variation in the responses to attitudinal statements (Sutton and Montello 2000). After extracting three underlying factors, I employed a varimax rotation to preserve orthogonality among the factors¹⁶ (Sutton and Montello 2000). Factor scores were compared across continuous variables of interest: respondents' age, length of residence, and number of questions answered correctly. The factor scores were also divided into subsets of residents near existing colonies and residents near potential colonies. For residents near existing colonies, the relationship between factor scores and distance from the prairie dog colony was assessed. Factor scores were tested for significant relationships with nominal (e.g., gender) and ordinal (e.g., knowledge categories) variables of interest through analysis of variance (ANOVA). Again, these statistical tests were also repeated for the residential subsets.

¹⁶ Orthogonal factors are uncorrelated.

Results

Remote Sensing

The final fraction image illustrated that prairie dog colony habitat was distinguishable from human-built structures, impervious surfaces, irrigated vegetation, and other non-habitat areas (see Figure 9). The constrained spectral mixture analysis modeled forty-eight percent of the pixels—the portion of the scene composed of soil, NPV, green vegetation, and minimal shade. With shade-dominated pixels unclassified, the dominant land cover in the scene was soil, followed by NPV, then green vegetation (see Table 1).

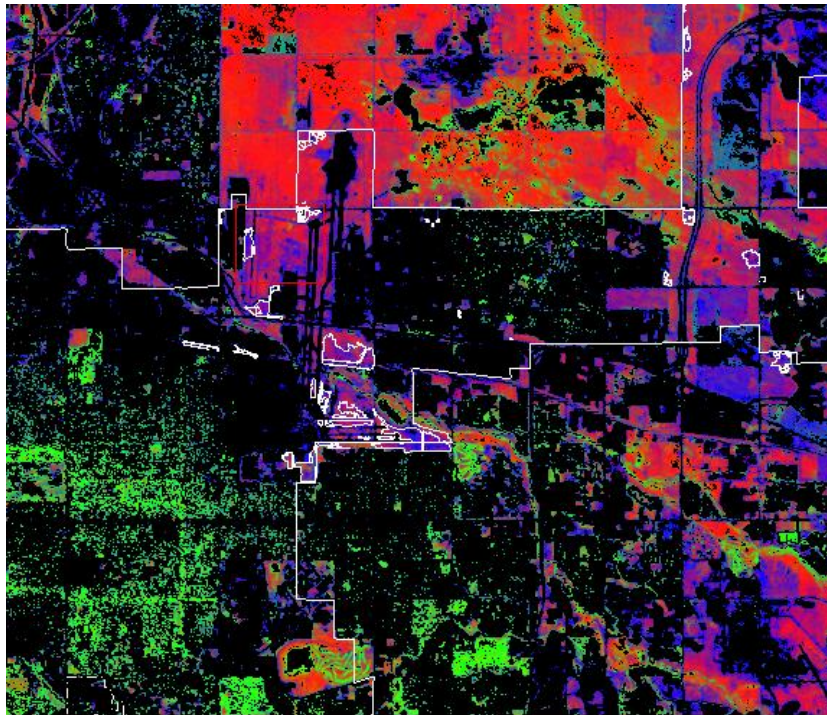


Figure 9. Subset of the shade-normalized fraction image. Displayed as NPV (red), GV (green), and soil (blue). As a result of the constraints, unclassified areas are black. The boundaries of Denver and colonies are shown in white.

Table 1. Statistics for the endmember fractions present in the unmixed scene.

Endmember	Mean Value (% per pixel)	Standard Deviation
NPV	0.38	0.27
GV	0.18	0.23
Soil	0.44	0.27

Focusing on known colony boundaries, characteristics of prairie dog habitat ranged widely; most pixels had fraction compositions from 25 to 75% NPV or soil (see Figure 10). Occupied colony space was generally dominated by senesced prairie grasses or soil, but both components were consistently present. Green vegetation composed a small proportion of the prairie dog habitat, with average pixel values around .05%. Error was acceptably low at all sampled colony pixels, with the highest RMSE value below 6.5 DN values (Powell et al. 2007). The majority of the image had RMSE less than 2.8 DN values.

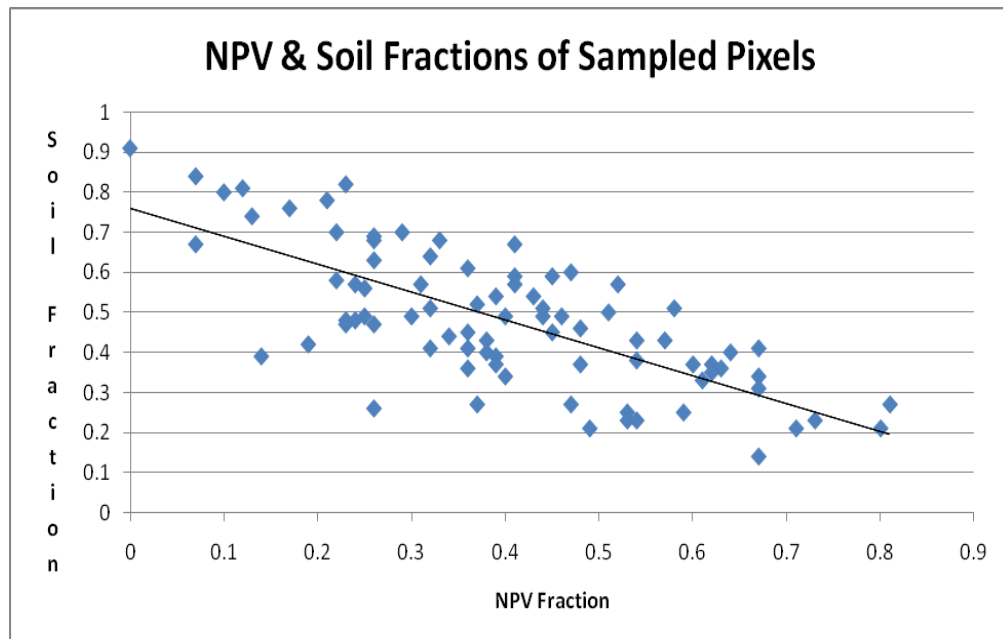


Figure 10. Plot of NPV and Soil fractions sampled from known colony pixels.

The supervised Mahalanobis distance classification of the shade-normalized fraction image classified each pixel into one of two classes: existing/potential prairie dog habitat and non-habitat areas. The existing/potential habitat class comprised 39% of the modeled pixels. These sites also may eventually serve as natural expansion or intentional relocation sites. The non-habitat class, which is 61% of the modeled pixels, contained urban land cover such as golf courses. The existing/potential habitat class provided the spatial framework for survey distribution.

Accuracy Assessment

An accuracy assessment measured how well the classified Landsat ETM+ image corresponded to independent reference data which identifies Denver's available prairie dog habitat. Previous studies have detected rural prairie dog colonies with 64% accuracy from satellite imagery, and 70% accuracy when GIS layers, such as slope and patch size, are incorporated (Assal & Lockwood 2007). For urban habitat, which is less continuous, such levels of accuracy are difficult to achieve. Classification methods applied to urban scenes often achieve an overall accuracy of approximately 50% (Tooke et al. 2009).

Ground sampling would be difficult as land cover and land use have undergone significant change since 2002.¹⁷ I utilized Google Earth (GE) imagery as reference data to

¹⁷Even after the accuracy assessment and the confirmation of selected sample locations with 2007 Google Earth imagery, a few selected potential colony sites had been developed. In the southeastern portion of the

assess the accuracy of the classified map of existing/potential habitat and non-habitat areas. The GE imagery for Denver was from June and July of 2007, which is seasonally similar to the August 2002 Landsat ETM+ image. While GE imagery has a lower spectral resolution than Landsat ETM+ satellite imagery, it has much finer spatial resolution. As a result, a user “is often able to readily discern land cover type, disturbance events, and other relevant attributes based solely on the [GE] imagery” (Potere 2008, 7974). GE imagery also has a horizontal positional accuracy that is sufficient for assessing the accuracy of classified, moderate-resolution scenes (Potere 2008, Potere et al. 2009). Thus, for the purposes of this research, the level of spatial and spectral detail available through GE imagery was sufficient to classify random points into binary categories: existing/potential prairie dog habitat or non-habitat areas.

Seventy random points were generated for the entire classified scene in ArcGIS 9.3 and the latitude and longitude were extracted for each point. Each point was located on the classified Landsat ETM+ image and the corresponding category was noted. This procedure was repeated in GE. The resulting confusion matrix indicates that the Landsat ETM+ image was classified with approximately 83% overall accuracy (see Table 2). The temporal mismatch between the classified image and the reference image resulted in relatively low accuracy for the habitat class; only 67% of the sampled points that were classified as habitat also appeared as habitat in the more recent GE imagery. However,

City and County of Denver, it was very difficult to find existing open space. One open space fragment had been turned into a bank and convenience store.

most of those incorrectly categorized points were found in housing subdivisions on the urban fringe, which is indicative of land use change over the period of time elapsed between the Landsat ETM+ image and the GE imagery collection. Some level of error is also expected due to geo-registration differences between the two images (e.g., Potere 2008).

Table 2. Error matrix from accuracy assessment of classified habitat and non-habitat Landsat ETM+ image and Google Earth imagery. Overall accuracy was 83%.

		Predicted Class (Landsat ETM+ model)		
		Non-Habitat	Habitat	Accuracy (%)
Reference Class (GE- derived)	Non-Habitat	42	8	84
	Habitat	4	16	80
	Accuracy (%)	91	67	83

Statistical Results

I received 234 surveys for a 23% response rate (11 surveys were unusable, incomplete either in significant portions or their entirety). Of the usable surveys, 103 contained the educational component and 120 did not (see Table 3). Of the 223 usable surveys, 151 came from residents living near existing colonies (68%), 69 from residents living near potential colony sites (31%), and 3 from other addresses (1%) (see Figure 8). This difference in response rate by residence type suggests a non-response bias from the sampled population near potential colonies, as their response rate was much lower.

Residents in Hampden—where there has been conflict due to prairie dogs expanding onto private property (A. DeLaup, wildlife ecologist, personal communication)—had the highest response rate at 48%. People who feel strongly about an issue, find it relevant to their lives, or are generally interested in the topic are more likely to voluntarily return a survey (Montello & Sutton 2006). Therefore, it is logical that residents living near colonies expressed greater interest in the subject matter.

Table 3. Summary of returned surveys.

	Total (Number)	Total (%)
Educational Component	103	46
Near Existing Colony	69	31
Near Existing Open Space	34	15
No Educational Component	120	54
Near Existing Colony	82	37
Near Existing Open Space	35	16
Neither	3	1

Forty-two percent of the survey respondents were male and fifty-eight percent were female. The average age of respondents was 50 years old (the standard deviation was 17 years and range was 72 years); the average length of residence at a respondent’s current location was 11 years, while the median was 5 years, indicating a positive skew in the data (the standard deviation was 13 years and the range was 54 years); the average length of residence in Denver was 24 years and the median was 20 years (the standard deviation was 20 years and the range was 81 years) (see Figure 11).

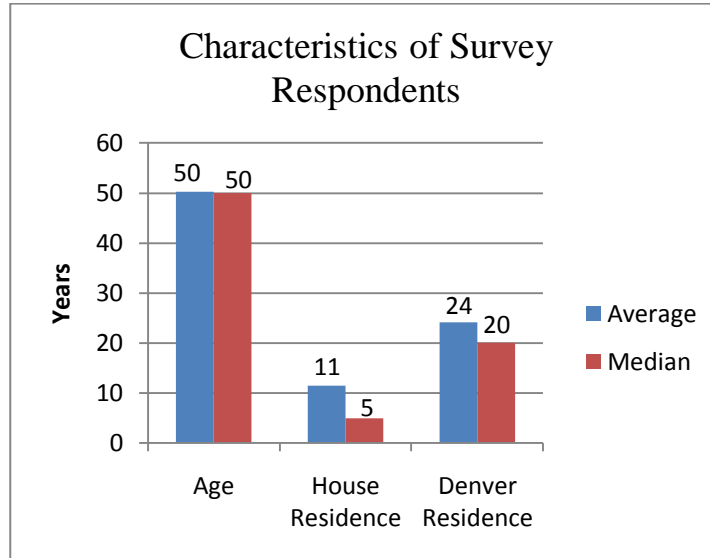


Figure 11. Summary of survey respondents' characteristics.

The average number of questions answered correctly was 2.5 and the median number of questions answered correctly was 2, out of 7 questions.¹⁸ This aggregate measure of knowledge did not exhibit significant differences based upon whether residents live near colonies or a potential colonies (see Table 4).

There was a wide range in the attitudinal responses (see Table 5 and Appendix B, Figures 12-21) among all respondents. A few examples: only 5% of respondents disagree or strongly disagree with the statement *I enjoy seeing hawks and eagles in my community*, which was the lowest rate of disagreement with any statement (see Appendix B, Figure 13). The statement *Lethal removal of prairie dogs should be the standard management*

¹⁸ One question (number 7) inadvertently included two correct answers, as new information about the presence of swift foxes in prairie dog burrows was found only after survey distribution. Both answers were counted as correct for that particular question and in the aggregated number of correct answers.

practice on public lands had roughly 20% of respondents agree or strongly agree (see Appendix B, Figure 15). Thirteen percent of respondents agree or strongly agree with the statement *Prairie dogs inhabit flat, open space that would be better used for urban development* (see Appendix B, Figure 21).

Table 4. Percentage of respondents answering questions correctly. The responses of residents living near colonies are compared to those living near potential colonies.

Correct Response to Question	Percentage Answering Correctly		χ^2	<i>p</i>
	Existing Colony	Potential Colony		
Female prairie dogs have one litter each year (around 3 pups).	11	13	0.07	0.79
Within the prairie landscape, black-tailed prairie dog colonies are a very important part of prairie ecosystems.	48	43	0.42	0.52
Compared to the early 1800s, the number of black-tailed prairie dogs in the United States has decreased dramatically.	32	33	0.05	0.82
Some ranchers fear that rural prairie dog colonies will cause cattle to break their legs in burrows and vegetation damage.	62	69	1.3	0.25
Prairie dog burrows provide nesting space and shelter for black-footed ferrets and swift foxes.	30	33	0.29	0.59
After the plague infects a prairie dog colony, none of the colony survives, rarely infecting other species that enter the colony.	9.2	9.7	0.01	0.91
Compared to the communication abilities of other mammals, prairie dogs have extraordinary communication abilities.	53	56	0.13	0.72
Overall Percentage Correct	35.0	36.7		

Table 5. Responses to attitudinal statements as a percentage of all responses.

Attitudinal Statement	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)	No Opinion (%)
I enjoy or would enjoy having prairie dogs live in my community.	16	24	24	12	22	2
I enjoy seeing hawks and eagles in my community.	33	43	13	2	3	5
Prairie dogs in Denver play an important role in keeping the natural prairie intact.	17	39	15	11	8	9
Lethal removal of prairie dogs should be the standard management practice on public lands.	9	11	15	24	35	7
Prairie dogs are harmful to ranching.	6	24	30	19	9	13
I support protecting prairie dogs in Denver.	20	24	23	9	16	8
Restoring native prairie habitat in Denver is important to me.	19	28	25	8	13	7
Plague outbreaks in prairie dogs are a threat to human health.	9	26	17	24	9	15
I would consider a nearby prairie dog colony to be a positive amenity in a Denver neighborhood.	12	27	19	18	19	4
Prairie dogs inhabit flat, open space that would be better used for urban development.	4	9	16	29	30	12

Categorical Analysis: All Respondents

For all respondents, there was no significant difference in attitudes based upon whether or not a respondent received educational information in their survey packet (see Table 6). The sole exception was the statement *Prairie dogs are harmful to ranching*, as those who had received educational information were significantly more likely to disagree or strongly disagree than those who had not received educational information ($\chi^2=10.3, p=0.04$).

Residence type—whether the survey respondent lived near an existing colony or a potential colony—exhibited significant differences for two statements (see Table 6). Residents living near colonies were significantly more likely to agree or strongly agree with the statement *I enjoy or would enjoy having prairie dogs live in my community* ($\chi^2=11.4, p=0.02$). Residents living near colonies were less likely to agree with the statement *Prairie dogs inhabit flat, open space that would be better used for urban development* than residents living near a potential colony ($\chi^2=9.88, p=0.04$).

Gender was strongly associated with different attitudes. On all six significant statements, females were more likely to be in favor of prairie landscapes and prairie dogs than males (see Table 6). For all statements, except *Prairie dogs are harmful to ranching* and *Plague outbreaks in prairie dogs are a threat to human health*, a majority of both genders were neutral, favorable, or strongly favorable towards prairie dogs and prairie landscapes. There was no relationship between gender and knowledge. Both genders were proportionately represented in residence type and receipt of educational

information. Men had lived in Denver slightly longer than women (15 years and 10 years, respectively) ($F=6.8, p=0.01$). Men were also slightly older than women (55 years and 48 years, respectively) ($F=9.3, p=0.003$).

Knowledge categories (i.e., low, moderate, and high¹⁹) were significantly associated with all statements except *Plague outbreaks in prairie dogs are a threat to human health* (see Table 6). For most statements, the pattern was consistent: those with low knowledge had the least favorable attitudes, those with moderate knowledge had favorable attitudes, and those with high knowledge had the most favorable attitudes towards prairie landscapes and prairie dogs. One statement, regarding support for lethal management of prairie dogs, deviated from this pattern, as those with high knowledge levels were more likely to be neutral, agree, or strongly agree with the statement than those with the moderate knowledge levels. The group with low knowledge levels had the highest degree of agreement with that statement.

Knowledge levels were disaggregated in order to compare individual questions to attitudinal responses. Respondents who correctly answered that *Prairie dog colonies are a very important part of prairie ecosystems* were always more positive towards prairie dogs and prairie landscapes (see Table 7) than those respondents who did not answer correctly. Respondents who correctly answered that *Prairie dogs have extraordinary*

¹⁹ Respondents placed in the low category answered 0 or 1 question correctly out of 7; respondents placed in the moderate category answered 2, 3, or 4 questions correctly; respondents placed in the high category answered 5, 6, or 7 questions correctly.

communication abilities were more positive towards prairie dogs and prairie landscapes on eight out of ten attitudinal statements (see Table 7).

Table 6. Comparison across all survey respondents based upon whether or not the respondent received educational information, residence type (i.e., existing colony or potential colony), gender (i.e., male or female), and knowledge categories (i.e., low, moderate, high). Significant results at the 5% level of significance are denoted with an *.

<i>Attitudinal Statement</i>	<i>Educational Information</i>		<i>Residence Type</i>		<i>Gender</i>		<i>Knowledge Categories</i>	
	χ^2	<i>p</i>	χ^2	<i>p</i>	χ^2	<i>p</i>	χ^2	<i>p</i>
I enjoy or would enjoy having prairie dogs live in my community.	1.7	0.80	11.4	0.02*	7.8	0.10	23.1	0.003*
I enjoy seeing hawks and eagles in my community.	9.0	0.06	6.30	0.18	0.1	0.9991	23.0	0.003*
Prairie dogs in Denver play an important role in keeping the natural prairie intact.	4.2	0.38	0.7	0.95	15.1	0.005*	26.4	0.0009*
Lethal removal of prairie dogs should be the standard management practice on public lands.	4.2	0.38	7.2	0.12	15.2	0.004*	34.6	<0.0001*
Prairie dogs are harmful to ranching.	10.4	0.04*	3.2	0.53	10.4	0.04*	15.9	0.0044*
I support protecting prairie dogs in Denver.	2.2	0.69	6.1	0.19	18.6	0.001*	25.7	0.0012*
Restoring native prairie habitat in Denver is important to me.	1.3	0.86	2.6	0.63	12.0	0.02*	33.7	<0.0001*
Plague outbreaks in prairie dogs are a threat to human health.	4.3	0.37	1.5	0.83	5.7	0.22	12.0	0.15
I would consider a nearby prairie dog colony to be a positive amenity in a Denver neighborhood.	7.3	0.12	8.8	0.07	9.00	0.06	27.0	0.0007*
Prairie dogs inhabit flat, open space that would be better used for urban development.	8.0	0.09	9.9	0.04*	11.5	0.02*	27.2	0.0007*

Table 7. Responses to individual questions compared to individual attitudinal statements for all respondents. Significant results at the 5% level of significance are denoted with an *.

<i>Attitudinal Statement</i>	Prairie dog burrows provide nesting space and shelter for black-footed ferrets and swift foxes.		After the plague infects a prairie dog colony, none of the colony survives and they rarely infect other species.		Prairie dogs have extraordinary communication abilities.	
	χ^2	<i>p</i>	χ^2	<i>p</i>	χ^2	<i>p</i>
I enjoy or would enjoy having prairie dogs live in my community.	1.9	0.75	3.1	0.54	17.9	0.0013*
I enjoy seeing hawks and eagles in my community.	5.9	0.20	5.6	0.23	6.3	0.18
Prairie dogs in Denver play an important role in keeping the natural prairie intact.	1.5	0.83	3.5	0.47	21.8	0.0002*
Lethal removal of prairie dogs should be the standard management practice on public lands.	3.0	0.56	4.1	0.40	12.8	0.0123*
Prairie dogs are harmful to ranching.	6.1	0.19	0.85	0.93	8.4	0.077
I support protecting prairie dogs in Denver.	1.2	0.88	2.2	0.70	12.9	0.0118*
Restoring native prairie habitat in Denver is important to me.	7.2	0.13	8.1	0.09	16.2	0.0028*
Plague outbreaks in prairie dogs are a threat to human health.	3.3	0.51	1.3	0.87	13.4	0.0094*
I would consider a nearby prairie dog colony to be a positive amenity in a Denver neighborhood.	6.3	0.18	0.55	0.97	23.4	0.0001*
Prairie dogs inhabit flat, open space that would be better used for urban development.	4.0	0.41	3.9	0.43	13.6	0.0086*

Table 7 continued. Responses to individual questions compared to individual attitudinal statements for all respondents. Significant results at the 5% level of significance are denoted with an *.

	Prairie dogs have one litter (two to three pups per year).		Prairie dog colonies are a very important part of prairie ecosystems.		The number of black-tailed prairie dogs has decreased dramatically.		Some ranchers fear that rural prairie dog colonies will cause cattle to break their legs and vegetation damage.	
<i>Attitudinal Statement</i>	χ^2	<i>p</i>	χ^2	<i>p</i>	χ^2	<i>p</i>	χ^2	<i>p</i>
I enjoy or would enjoy having prairie dogs live in my community.	2.3	0.67	37.1	<0.0001*	9.3	0.05	10.1	0.04*
I enjoy seeing hawks and eagles in my community.	5.1	0.28	20.8	0.0003*	13.1	0.011*	7.2	0.13
Prairie dogs in Denver play an important role in keeping the natural prairie intact.	4.4	0.36	39.4	<0.0001*	5.3	0.25	2.9	0.58
Lethal removal of prairie dogs should be the standard management practice on public lands.	5.3	0.26	34.5	<0.0001*	5.6	0.23	1.1	0.90
Prairie dogs are harmful to ranching.	4.1	0.39	15.2	0.0042*	4.4	0.35	4.7	0.32
I support protecting prairie dogs in Denver.	4.5	0.35	39.1	<0.0001*	6.5	0.16	1.3	0.86
Restoring native prairie habitat in Denver is important to me.	5.2	0.27	32.1	<0.0001*	5.2	0.26	3.7	0.44
Plague outbreaks in prairie dogs are a threat to human health.	2.6	0.63	14.3	0.0065*	8.2	0.09	3.3	0.51
I would consider a nearby prairie dog colony to be a positive amenity in a Denver neighborhood.	3.5	0.48	40.7	<0.0001*	11.3	0.023*	2.5	0.64
Prairie dogs inhabit flat, open space that would be better used for urban development.	4.2	0.38	30.4	<0.0001*	8.1	0.09	7.6	0.11

Categorical Analysis: Respondents Living Near Existing Colonies

For respondents living near a colony, there was no significant difference based upon whether or not educational information was received (see Table 8). Only *Prairie dogs inhabit flat, open space that would be better used for urban development* resulted in a significant difference ($\chi^2=10.4$, $p=0.03$). Those that received educational information were more likely have a neutral opinion; while those who did not receive an educational portion were more likely to either disagree or agree. Those who received an educational portion were also more likely to strongly agree with the above statement. Thus, while the difference across these categories was significant, it did not trend in a singular direction.

Regarding gender, females living near a colony were consistently and significantly more supportive of prairie landscapes and prairie dogs than males (see Table 8). For each statement, more than 50% of female respondents were strongly in favor, in favor, or neutral towards prairie landscapes and prairie dogs.

Knowledge categories exhibited significant differences on every attitudinal statement except *Plague outbreaks in prairie dogs are a threat to human health* (see Table 8). The same general pattern found among all respondents holds for the subset living near a colony: those in the high knowledge category have most favorable attitudes towards the prairie landscape and prairie dogs, those with moderate knowledge have favorable attitudes, and those with low knowledge have the least favorable attitudes. There were a few exceptions. For the statements *Lethal removal of prairie dogs should be the standard management practice on public lands* and *Prairie dogs are harmful to*

ranching, respondents with moderate levels of knowledge had more favorable attitudes than respondents with high levels of knowledge.

Table 8. Comparison from residents living near an existing colony based upon whether or not the respondent received educational information, gender (i.e., male or female), and knowledge categories (i.e., low, moderate, high). Significant results at the 5% level of significance are denoted with an *.

<i>Attitudinal Statement</i>	<i>Educational Information</i>		<i>Gender</i>		<i>Knowledge Categories</i>	
	χ^2	<i>p</i>	χ^2	<i>p</i>	χ^2	<i>p</i>
I enjoy or would enjoy having prairie dogs live in my community.	2.5	0.64	7.9	0.10	28.2	0.0004*
I enjoy seeing hawks and eagles in my community.	4.5	0.34	0.72	0.95	19.9	0.011*
Prairie dogs in Denver play an important role in keeping the natural prairie intact.	2.8	0.59	11.2	0.03*	35.3	<0.0001*
Lethal removal of prairie dogs should be the standard management practice on public lands.	4.8	0.31	10.2	0.04*	34.6	<0.0001*
Prairie dogs are harmful to ranching.	5.0	0.29	17.2	0.002*	22.9	0.004*
I support protecting prairie dogs in Denver.	0.35	0.99	14.6	0.006*	25.7	0.0012*
Restoring native prairie habitat in Denver is important to me.	1.3	0.87	15.2	0.004*	27.6	0.0006*
Plague outbreaks in prairie dogs are a threat to human health.	4.6	0.33	6.6	0.16	13.1	0.11
I would consider a nearby prairie dog colony to be a positive amenity in a Denver neighborhood.	2.1	0.72	8.2	0.08	26.5	0.0009*
Prairie dogs inhabit flat, open space that would be better used for urban development.	10.4	0.03*	15.8	0.003*	20.6	0.0084*

Categorical Analysis: Respondents Living Near Potential Colonies

For those living near potential colonies, there was no significant difference based upon whether or not educational information was received associated with most of the attitudinal statements (see Table 9). The statement *I would consider a nearby prairie dog colony to be a positive amenity in a Denver neighborhood* exhibited a significant difference ($\chi^2=11.43, p=0.02$), as respondents who received educational information were more likely to agree with that statement. However, they were also more likely to strongly disagree, and less likely to strongly agree, than respondents who did not receive educational information. The attitudinal difference based upon educational information did not trend in a singular direction.

There was no significant difference in attitudinal responses based upon knowledge levels (see Table 9), although the same general trend persisted, as those with higher and moderate levels of knowledge tended to have more favorable attitudes towards prairie dogs and prairie landscapes than those with low knowledge levels.

Gender was only significant for two statements (see Table 9): *Prairie dogs in Denver play an important role in keeping the natural prairie intact* ($\chi^2=12.7, p=0.013$) and *I support protecting prairie dogs in Denver* ($\chi^2=11.04, p=0.026$). For both statements, females were significantly more likely than males to strongly agree, agree, or be neutral.

Table 9. Comparison from residents living near a potential colony site based upon whether or not the respondent received educational information, gender (i.e., male or female), and knowledge categories (i.e., low, moderate, high). Significant results at the 5% level of significance are denoted with an *.

<i>Attitudinal Statement</i>	<i>Educational Information</i>		<i>Gender</i>		<i>Knowledge Categories</i>	
	χ^2	<i>p</i>	χ^2	<i>p</i>	χ^2	<i>p</i>
I enjoy or would enjoy having prairie dogs live in my community.	4.3	0.37	9.2	0.06	8.1	0.42
I enjoy seeing hawks and eagles in my community.	6.8	0.15	2.0	0.75	7.6	0.63
Prairie dogs in Denver play an important role in keeping the natural prairie intact.	4.7	0.32	12.7	0.013*	2.6	0.96
Lethal removal of prairie dogs should be the standard management practice on public lands.	0.9	0.92	8.7	0.07	8.8	0.36
Prairie dogs are harmful to ranching.	7.4	0.11	3.7	0.45	11.9	0.16
I support protecting prairie dogs in Denver.	9.2	0.06	11.0	0.026*	13.0	0.11
Restoring native prairie habitat in Denver is important to me.	0.4	0.98	0.5	0.97	10.2	0.25
Plague outbreaks in prairie dogs are a threat to human health.	0.7	0.95	4.1	0.39	7.2	0.52
I would consider a nearby prairie dog colony to be a positive amenity in a Denver neighborhood.	11.4	0.02*	6.6	0.16	5.1	0.74
Prairie dogs inhabit flat, open space that would be better used for urban development.	1.5	0.83	3.2	0.52	13.0	0.11

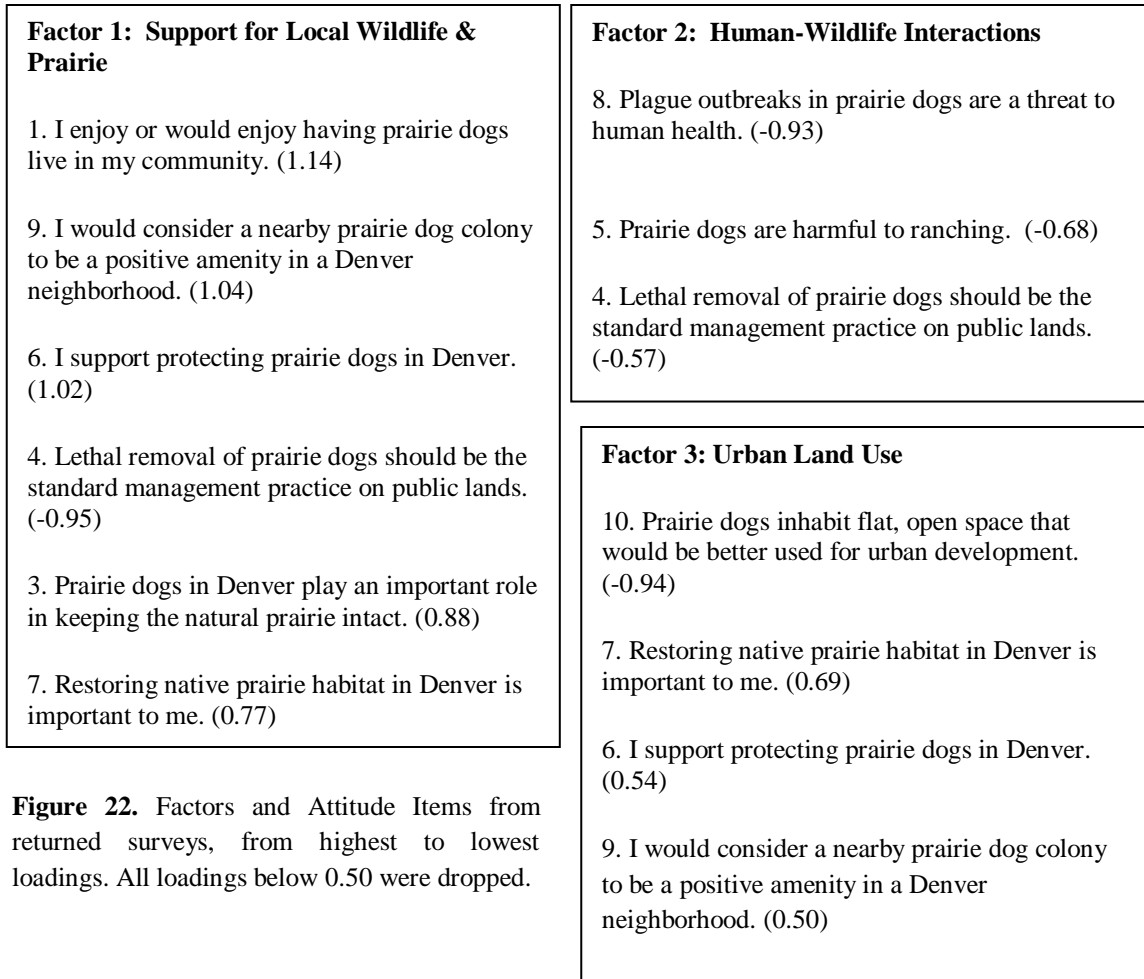
Factor Analysis

The three extracted factors capture underlying dimensions to respondents' attitudinal responses. Together, these factors explained 78% of the overall variation in attitudes. The statements comprising each factor are presented in decreasing order of loading, and statements with loadings below the 0.50 threshold were not included in the factors (see Figure 22).

The first factor, interpreted as *Support for Local Wildlife & Prairie*, had an Eigenvalue of 9.5 and explained 68% of the variation in attitudinal responses. The statements in this factor specifically mention protecting or restoring local prairie dog populations and local prairie spaces. Variation in these statements is likely influenced by respondents' attitudes and beliefs regarding active environmental protection. This factor seems to capture substantial support for sustaining urban prairie dogs.

The second factor, characterized as *Human-Wildlife Interactions*, had an Eigenvalue of 0.76 and explained 5% of the variation in attitudes. This factor loaded with statements connected to the complex interactions between wildlife and humans, as both statements discussing prairie dogs' direct impact on humans were included. This factor also appears to be measuring urban respondents' distaste for lethal management of prairie dogs.

The third factor, described as *Urban Land Use*, had an Eigenvalue of 0.73 and explained 5% of the variation in attitudes. All the statements in this factor touch upon the value of including prairie dogs and prairie habitat in a human-dominated urban landscape. The statements in this factor correspond with a desire to protect prairie dogs and prairie spaces from urban development.



For all residents, factor scores did not differ significantly in relation to respondents' age, length of residence, and knowledge.²⁰ The few significant relationships were weak. *Support for Local Wildlife & Prairie* differed significantly as a function of respondent's age ($r=-0.24$, $r^2=0.06$, $p=0.0003$), length of residence at the current household ($r=-0.17$, $r^2=0.03$, $p=0.01$), and knowledge, in terms of questions answered correctly ($r=0.26$, $r^2=0.07$, $p<0.0001$).

No factors exhibited a difference based upon residence type. The factors *Support for Local Wildlife & Prairie* and *Urban Land Use* lacked significant differences as a function of educational information. Those respondents who received educational information had significantly higher factor scores than those who did not receive educational information for *Human-Wildlife Interactions* ($p=0.002$).

Factor scores for *Human-Wildlife Interactions* did not exhibit significant differences based upon gender or knowledge (see Table 10). *Support for Local Wildlife & Prairie* and *Urban Land Use* factor scores differed based upon gender ($p=0.01$, $p=0.03$, respectively) Female respondents had significantly higher scores for those two factors.

²⁰ These variables were treated as continuous variables for the purposes of leveraging regression analyses with the factor scores (Sutton and Montello 2000).

Table 10. Difference in factor scores of attitude across four variables of interest for all respondents. Two sample t-tests that resulted in significance level at the 0.05 threshold are noted with *.

	Educational Information	Residence Type	Gender	Knowledge Level
1. Support for Local Wildlife & Prairie			*	*
2. Human-Wildlife Interactions	*			
3. Urban Land Use			*	*

Respondents who displayed high or moderate knowledge had greater factor scores than those who displayed low knowledge for *Support for Local Wildlife & Prairie* ($p=0.0002$). Factor scores for *Urban Land Use* also varied as a function of knowledge, as respondents with high levels of knowledge exhibited higher factor scores than those with low levels of knowledge ($p=0.006$).

For the residents near colonies, there was no difference in factor scores related to distance from colony (in miles). Knowledge was not related to a resident's distance from a colony. Knowledge, measured by the number of questions answered correctly, was weakly related to factor scores for *Support for Local Wildlife & Prairie* ($r=0.34$, $r^2=0.12$, $p<0.0001$). The factor scores for *Support for Local Wildlife & Prairie* ($p<0.0001$) and *Urban Land Use* ($p=0.02$) varied as a function of ordinal knowledge categories (see Table 11). Those in the high or moderate knowledge categories were significantly more positive in their attitudes than those in the low knowledge category.

Table 11. Difference in factor scores of attitude across three variables of interest for the existing colony subset. Two sample t-tests that resulted in significance level at the 0.05 threshold are noted with *.

	Educational Information	Gender	Knowledge Level
1. Support for Local Wildlife & Prairie			*
2. Human-Wildlife Interactions	*	*	
3. Urban Land Use		*	*

Those who received educational information had higher scores for *Human-Wildlife Interactions* than those who received no educational information ($p=0.003$). None of the other factors exhibited a relationship with the presence of educational information. There was no difference based upon gender for *Support for Local Wildlife & Prairie*, but females exhibited higher factor scores than males for *Human-Wildlife Interactions* ($p=0.02$) and *Urban Land Use* ($p=0.003$).

For residents near potential colonies, there was no significant relationship between knowledge and two factors (see Table 12). Scores for the factor *Urban Land Use* varied significantly as a function of knowledge ($r=0.29$, $r^2=0.08$, $p=0.015$). Females demonstrated higher scores than males for *Support for Local Wildlife & Prairie*. There was no significant relationship between gender and the other factors; there was also no significant relationship based upon the inclusion of educational information for any of the factors.

Table 12. Difference in factor scores of attitude across three variables of interest for the potential colony subset. Two sample t-tests that resulted in significance level at the 0.05 threshold are noted with *.

	Educational Information	Gender	Knowledge Level
1. Support for Local Wildlife & Prairie		*	
2. Human-Wildlife Interactions			
3. Urban Land Use			*

Discussion

Nature undergirds the well-being of society, while society bounds and constructs nature across time and space. The existing construct of nature in the United States means that wilderness and wildlife is a privileged status given to pristine environments and charismatic animals. Local ecosystems are often under-appreciated (Cronon 1995). One consequence of this division is that our cities have far too little space for urban wildlife, and these creatures are rarely accepted as part of the urban landscape. Urban wildlife, and especially the conflict that often emerges around its presence, therefore cannot be separated into ecological and social components when considering the long-term viability of a species. Mixed methods provide a more holistic view of these real and tangible problems.

The dual approach of remote sensing analysis and statistical methods provided useful insight into the viability of Denver's prairie dogs. The remote sensing analysis, supplemented with GIS information, determined that there is additional space for prairie dogs within the central city boundary. The habitat classification identified residences based upon the type of open space near their homes: potential colonies, which are open prairie spaces that meet certain parameters, or existing colonies, which are currently occupied prairie dog colonies. This classification also facilitated a statistical examination

of knowledge and attitudinal patterns towards prairie dogs in Denver. Without the ecological foundation derived through remote sensing, the statistical analysis would not provide the same degree of insight into the social viability of prairie dogs.

In the rapidly sprawling Front Range, limited habitat is an obvious problem. While prairie dogs provide value for human and wildlife communities, they are being squeezed out of this sprawling conurbation in favor of other urban uses, such as highway expansion. Connectivity of remaining habitat will likely prove to be a long-term constraint on urban prairie dogs (Magle & Crooks 2009). Prairie dogs are not allowed onto groomed areas, but can expand onto existing natural space (A. DeLaup, wildlife ecologist, personal communication, Feb. 2010). This is a social limitation of their distribution rather than a biological one, as prairie dogs cannot distinguish between a soccer field and an area designated as natural space. Denver's Parks and Recreation Department wants to support prairie dog colonies, yet developers and private landowners will typically exterminate colonies that interfere with human use. Residents also hold a wide range of views towards prairie dogs, so there is no broad consensus supporting urban prairie dog restoration or their wholesale extermination.²¹ Given these ecological and social constraints, the long-term viability of Denver's prairie dogs is precarious. However, the mixed methods employed in this research show that there is viable space for prairie dogs in the city, and urban neighborhoods can be accepting of these animals.

²¹ Urban residents tend to be more favorable towards prairie dogs than rural residents, but this does not mean that in absolute terms they are favorable towards prairie dogs.

In the metropolitan area of Denver, Colorado, a four-endmember model was sufficient to analyze land cover composition of prairie dog habitat and extend those characteristics to existing open space in the metropolitan area. A supervised Mahalanobis distance classification of the resulting fraction images successfully distinguished potential and existing metropolitan habitat from non-habitat urban areas with 83% accuracy. Existing colonies consisted primarily of NPV and soil, with very small fractions of green vegetation and effectively no shade component.

Thus, the expected structure and biophysical composition of rural prairie dog colonies extends to the urban setting of Denver. However, the variability of soil and NPV fractional composition was larger than anticipated; these components are also difficult to separate spectrally. Many colony pixels were dominated by soil, indicating that an urban setting may result in occupation of more marginal habitat by prairie dogs. Colony expansion is difficult, so drought and other environmental pressures have a greater impact on these densely-populated colonies.

Landscape-scale analyses of urban areas can be used to extract a generalized range of potential open space that could fit prairie dogs' typical habitat requirements. The rapid pace of urban development means that these open spaces will continue to disappear without concerted efforts to provide space for wildlife. The long history of negative attitudes towards prairie dogs in the western United States, combined with conceptions of urban environments as human domains, further indicates that this urban wildlife species faces numerous challenges. Yet, prairie dogs could provide a unique catalyst for

conserving prairie spaces in Denver, as protecting even limited urban colonies may allow this keystone species to support local fauna.

The data collected through the survey focused on patterns in attitudes towards prairie dogs as a function of basic demographics, location, education, and knowledge. Disaggregating the data along residence type allowed additional insight into the relationships occurring in the general population compared to those living near colonies. Therefore, this discussion will integrate both categorical analysis and factor analysis in discussing the major variables of interest—educational information, residence type, gender, and knowledge—and their relationships with urban residents' attitudes.

This research identified new patterns in knowledge, attitudes, location, and demographics compared to studies operating on a rural to urban gradient and some variables previously shown to be associated with attitudes and beliefs were contradicted. For example, distance from the nearest prairie dog colony had no relationship to Denver residents' knowledge or attitudes (in contrast to Zinn & Andelt 1999). The lack of correlation between length of residence in Denver or length of residence at the current household and all three factors indicates that residents do not develop negative attitudes towards prairie dogs over increased time in their proximity. In addition, residents living closer to colonies do not have more knowledge about prairie dogs.

Attitudes varied considerably among respondents, which is not surprising given regional stereotypes (see Figures 12-21). The entrenched separation between culture and nature also emerged in responses, as residents tended to be noticeably ambivalent about

restoring or protecting prairie in Denver. This finding implies that prairie preservation is not a high priority among urban residents. However, residents were simultaneously strongly against using prairie dog colonies for urban development, as 59% of respondents disagreed to some degree with the removal of colonies for such purposes. Prairie dogs give these open prairie spaces a visible use and value. Prairie dogs may put a ‘face’ on development—it is much less problematic to develop vacant prairie space than it is to remove visible wildlife from that space.

It appears that the plague is much more of an explicit concern to urban residents than prairie dogs’ impacts on ranching. More than a third of residents were neutral about the impact of prairie dogs on ranching; yet, only about one-fifth were neutral about the impact of prairie dogs on human health. Residents with high levels of knowledge felt more strongly that the plague was a human health threat than residents with moderate levels of knowledge; they were also more likely to agree with lethal management techniques than residents with moderate knowledge. These residents, due to higher knowledge levels, may be more aware of potential threats to human health arising from local prairie dogs. Clearly, despite the relationship between knowledge and favorable attitudes towards prairie dogs, residents with all levels of knowledge must be targeted for educational outreach in order to alter beliefs about the risks of plague transmission.

Factor analysis provided another opportunity to examine attitudinal and demographic patterns. *Support for Local Wildlife and Prairie* was the most powerful factor, explaining nearly 70% of the variation in attitudes. This factor captures general

favorability towards local prairie dogs and native prairie ecosystems. Positive attitudes captured by this factor reflect a pro-environment bent among the sampled population. The next factor, *Human-Wildlife Interactions*, captures the fears of plague as well as the tense relationship between prairie dogs and ranching. Finally, the factor *Urban Land Use* consists of statements touching on the nature of what it means for a place to be urban, and whether that space can include prairie dog colonies and prairie habitat. This factor also includes the statement *I would consider a nearby prairie dog colony to be an amenity in a Denver neighborhood.*

A single statement did not appear in any of the factors—*I enjoy seeing hawks and eagles in my community.* Respondents overwhelmingly agreed with this statement. Attitudinal responses to this statement did not co-vary in a predictable and systematic way; regardless of other views on prairie dogs, respondents overwhelmingly viewed hawks and eagles favorably. Thus, it appears that respondents do not associate the presence of charismatic birds of prey with local prairie dog colonies. Knowledge of this association could result in increased support for local prairie dog colonies, as raptors are revered while their food supply is designated as a pest species. The predator-prey link may be the most effective argument, in terms of changing residents' attitudes, for sustaining urban prairie dogs.

Educational Information

The relatively brief educational information included in the survey was not effective in changing attitudes. It is also possible that survey respondents felt they were being lectured to with the explanatory answers. Furthermore, those with pre-existing unfavorable attitudes towards prairie dogs may have perceived explanations of their ecological importance as biased. However, educational information was associated with higher rates of disagreement for the statement *Prairie dogs are harmful to ranching*, which is one of the deeply entrenched viewpoints that led to the large-scale extermination of prairie dogs. Nevertheless, only a minority disagreed or strongly disagreed with that statement. Biases rooted in the long history of ranching in the western United States remain important in contemporary attitudes towards prairie dogs. At the same time, residents who received educational information were associated with higher factor scores for *Human-Wildlife Interactions*, implying that minimal educational information can begin to alter ranching prejudices and fears of the plague.

Residence Type

Residence type²² was expected to produce different attitudinal responses. Zinn & Andelt found the general population of Fort Collins, Colorado, to be more favorable towards prairie dogs than those living near colonies (1999). However, in Denver's

²² Near an existing colony or potential colony.

contemporary population, this pattern did not emerge. There was no consistent variation in attitudinal responses based upon residence type and no significant difference in any of the factors based upon residence type. However, there were two attitudinal statements with interesting results.

First, residents near existing colonies were more likely to agree or strongly agree with the statement *I enjoy or would enjoy having prairie dogs live in my community*. Second, residents near potential colonies were much more likely to agree or strongly agree with the statement *Prairie dogs inhabit flat, open space that would be better used for urban development* than residents near existing colonies. Residents living near a colony enjoy their burrowing neighbors and are more likely to disagree or strongly disagree that urban prairie spaces should be developed for human use.

There are several possible underlying causes. The most optimistic is that regardless of previous viewpoints, residents become charmed by their social backyard neighbors and ignore both perceived and actual costs to landscaping and human health. Because the residences classified as near a colony ranged from .01 miles to .50 miles away from a colony, another possibility is that most respondents do not find prairie dogs literally in their backyard. There is enough distance to minimize conflict; in the case of apartment buildings, residents may not agonize about their own lawns being damaged by prairie dogs.

Another potential confounding factor is that residents who do not like prairie dogs end up moving in order to escape the chattering, burrowing rodents. Yet another

possible cause is that residents who live near colonies but feel neutral towards or dislike prairie dogs did not respond to the survey. However, the range of responses included many unfavorable responses regarding prairie dogs. It is therefore difficult to conclude that only those with positive attitudes towards prairie dogs responded to the survey. There is strong evidence for a substantive difference in respondents' attitudes towards local prairie dogs based upon residence type. Therefore, if the Department of Parks and Recreation eventually relocates prairie dogs to new colony sites, it is possible that time will be an ally in improving human-prairie dog relationships.

Gender

Among all respondents, gender was significantly associated with attitudinal responses. Females were more positive towards prairie dogs and prairie landscapes, although they were not significantly different from males on statements concerning the perceived health threat of plague, the desirability of local prairie dogs, and the desirability of local hawks and eagles. Female respondents did not know more about prairie dogs than male respondents. While female respondents were, on average, slightly younger, this difference in age (about 5 years) does not logically account for the consistent difference in attitudes. Rather, women tend to hold more pro-environment attitudes (Reading et al. 2006). Another factor may be the ranching prejudice against prairie dogs, which permeates even urban areas. Women may be less interested in this connection than men and not feel that traditional livelihoods are threatened by these

scampering animals. It is also possible the females are more easily charmed by the antics of nearby prairie dogs, as they are cute, active social creatures. Furthermore, women may be more likely to engage in educational activities with their children, such as Prairie Dog Day at the Denver Zoo, and their attitudes about prairie dogs are molded in those settings.

Factor scores for *Support for Local Wildlife & Prairie* and *Urban Land Use* varied as a function of gender. Females had higher scores than males. This pattern supports the categorical analysis results. There was no difference in gender associated with *Human-Wildlife Interactions*, which, in conjunction with the lack of a significant difference on the attitudinal statement regarding the plague, indicates that fears of the plague reduce positive attitudes towards prairie dogs among women.

One interesting pattern emerged from the potential colony subset. Women who live near potential colonies did not exhibit significantly more favorable attitudes towards prairie dogs than men. This provides support for the postulation that women who live near colonies become charmed by prairie dogs' antics and develop more positive attitudes towards the species. Therefore, women who do not observe prairie dogs do not have the same number of opportunities to appreciate these creatures. The lack of statistically significant differences for the attitudinal statements could also be a product of small sample size (n=69). However, factor analysis indicates that female respondents who live near potential colonies are more likely to hold pro-environment attitudes than male respondents, as women in this subset had higher scores for *Support for Local Wildlife and Prairie*.

Knowledge

Ecological knowledge has previously been associated with increased support for lethal management of prairie dogs (Zinn & Andelt 1999). This pattern did not hold in Denver. Fifty-nine percent of residents were against or strongly against lethal management. Knowledge, when measured as the number of questions answered correctly, did not show a relationship with any of the factors. Knowledge did not decrease with distance from a colony; proximity to prairie dogs in Denver does not substantially impact knowledge. Urban residents may have less long-term empirical knowledge to draw upon compared to rural residents (Zinn & Andelt 1999). Furthermore, living a quarter of a mile away from a prairie dog colony is very different in an urban setting than a rural setting. In a city such as Denver, that quarter mile does not provide an unobstructed view of the colony. Rather, colonies are fairly small and often bounded by human structures.

There are questions for which a correct response had a notable and positive impact on almost all attitudes: prairie dogs' keystone species role and their extraordinary communication abilities. The keystone species angle is one of the strongest arguments in favor of conserving and restoring prairie dog populations; as a bonus, it improves attitudes towards Denver's prairie dogs. Residents who see prairie dogs every day might like them, feel neutral, or dislike them, but once they learn about their critical ecological role, may feel more positively towards local prairie dogs. These residents have probably

made the association between the presence of prairie dogs and the presence of hawks and eagles. The advanced communication abilities of prairie dogs imbues them with a charismatic intelligence—people who know that they have a language may enjoy watching them ‘talking,’ while others might perceive it as noise.

Once knowledge was transformed from the number of questions answered correctly into levels of low, moderate, and high, interesting relationships emerged. Those with low levels of knowledge were more likely to hold negative attitudes towards prairie dogs on all attitudinal statements except *Plague outbreaks in prairie dogs are a threat to human health*. In that case, those with higher levels of knowledge were more likely to strongly agree or agree with that statement. It appears this fear is substantially entrenched in Denver’s residents, and even more so among those with additional knowledge of prairie dogs. Perception of risk greatly impacts attitudes (Lybecker et al. 2002). Residents with higher knowledge are informed to the extent that they understand the association with prairie dogs and the plague, although they do not appear to fully believe that the risk to humans is exceptionally low. A lowered perception of risk should lead to more positive attitudes. Thus far, residents’ knowledge has not reached a critical point where all of the prairie dog myths have been debunked. Fear of the plague remains a powerful force behind anti-prairie dog sentiments in this setting.

Potential issues of non-response bias in this analysis should be noted. Residents near colonies were more likely to respond than residents living near potential colonies. Clearly, those with frequent interactions with prairie dogs—whether positive or

negative—were more interested in the survey than the population at large (represented by those living near the classified open prairie that acted as a proxy for potential colonies). Furthermore, another non-response bias appeared from the higher proportion of women who responded to the survey. This is potentially a result of volunteerism; only one survey was distributed to each sampled household, so women in the sampled households might have been more pro-active in returning the survey than men in the sampled households. The exact impact of this non-response bias is difficult to assess, as there was no follow-up to increase survey response; however, a recent study on beliefs and attitudes associated with prairie dogs in the Denver metropolitan area found only minimal differences between survey respondents and non-survey respondents (Milley 2008).

This survey was not able to measure each and every variable that might contribute to residents' attitudes towards Denver's prairie dogs. Nonetheless, the results strongly suggest that even moderate knowledge about prairie landscapes and prairie dogs improves attitudes. Educational efforts should focus on prairie dogs' role as a keystone species—specifically with regards to hawks and eagles—and their advanced communication abilities. Consistent and persistent education should make progress in debunking fears of the plague among urban residents. Furthermore, the gender gap in attitudes indicates that outreach efforts should focus on men. Despite these challenges, the social environment for prairie dogs in Denver appears surprisingly positive. Many residents living near colonies like their prairie dogs; hopefully this species will prove to be an urban wildlife success story.

Conclusion

This urban wildlife case study shows that prairie dogs can be sustained in the City and County of Denver. While residents vary in attitudes, there are encouraging signs that targeted ecological education can and will significantly improve attitudes towards prairie dogs. However, concerted efforts are needed to mitigate the rapid development of the metropolis and the impact on prairie dog colonies. The ecological reality of a growing city appears to be much more threatening to the viability of urban prairie dog colonies than social conflicts engendered by their presence.

There is much additional ecological and social fieldwork that could be immediately useful to the long-term conservation of prairie dogs. These topics range from basic to complex. Accurate population counts, surveys of species present in urban colonies, the potential for local and regional corridors, restoration of urban colonies, and the restoration of colonies on national grasslands are all topics of extraordinary importance. At the same time, research on regional and local perceptions of prairie dogs is vital, for understanding how and what people know about prairie ecosystems can help aid conservation efforts and exert pressure on appropriate levels of government to facilitate grasslands protection.

More broadly, future urban wildlife research is needed to improve the outlook for sustainable urban biodiversity. There is a significant need for basic, in-depth research and broader foundational theories. A European symposium in 2008 delineated five critical urban wildlife themes that demand attention: the physicality, human experience, valuation, management, and governance of urban green space (James et al. 2009). Critical questions regarding wildlife that should be explored include: What native animals can make a comeback in city spaces? How can urban planning facilitate this process? How can corridors be created to minimize road crossings? Local socio-economic environments are not static; neither are local green spaces. How have these changed over time, and what does it mean for urban wildlife in terms of habitat? How do socio-economic community changes impact human-wildlife interactions? How do people ‘manage’ urban wildlife and what are the actual effects on both animals and humans? “How can urban green spaces be designed and managed and provide access to experience nature for the urban population and still meet national and regional biodiversity targets?” (James et al. 2009, 70). The research I have presented addresses only a small portion of this agenda by focusing on the ecological and social potential for prairie dogs to be sustained in Denver.

One of the basic assumptions of this research is that there remains a need to re-conceptualize urban space. It should be a place for humans and animals alike, where native green spaces are connected with stable corridors. Wildlife deserves appreciation and support as part of the urban mosaic. In order to accept wildlife into the urban landscape, we must reconsider our expectations of cities. They are not places away from

nature; rather, they are places that benefit from the presence of resilient native ecosystems.

Residents need education on appropriate human-wildlife interactions; city planners need education on conserving and creating space for ecological communities. Urbanization is responsible for enormous amounts of habitat loss and fragmentation, and a concerted and sustained effort is required to mitigate the extraordinary pressure humans are placing on natural systems. The challenge will be incorporating these complex ecological and social phenomena into effective policy.

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Appendix A: Survey Instrument

Dear Denver Resident:

You are being asked to participate in this survey to help inform how the Parks and Recreation Department can manage black-tailed prairie dogs in the City and County of Denver. We are researchers at the University of Denver in the Department of Geography, working with the Parks and Recreation Department on this urban wildlife issue. We are interested in public perceptions and knowledge of prairie dogs. We also want to understand the public's experiences with prairie dogs.

Please provide your feedback. The point of the survey is to assess what Denver's residents know and think about prairie dogs, so do not search for the answers. Please respond to every question as best you can. The attached survey is short, about 5 to 10 minutes long, with room for comments at the end.

After completing the survey, please enclose it in the provided self-addressed and stamped envelope and mail it back. Survey participation is voluntary and your identity will remain anonymous. By completing the survey, you confirm that you are at least 18 years old.

Thank you for your participation in this research.

Sincerely,

Lauren Morse
Department of Geography
Division of Natural Sciences and Mathematics
University of Denver
2050 E. Iliff Avenue
Denver, CO 80208-0710

Appendix A: Survey Instrument

_____ Length of residence (in years) at current address _____ Age (in years)

_____ Length of residence (in years) in Denver _____ Gender (Male or Female)

_____ Nearest Street Intersection (example: Iliff Ave & University Blvd)

_____ Zip code

Section 1a—Please answer all of the questions to the best of your ability. Please circle only ONE ANSWER for each question.

1. How often do you see black-tailed prairie dogs?

Never Rarely Sometimes Every day

2. How close do you live to a black-tailed prairie dog colony?

1 or 2 houses away 3 houses to a block away

More than a block away I don't know where the nearest colony is

3. How many litters of young (each litter is around 3 pups) do female prairie dogs have each year?

1 litter 2 litters 3 or more litters Don't know

4. Within the prairie landscape, black-tailed prairie dog colonies are:

An insignificant part of prairie ecosystems A very important part of prairie ecosystems

Harmful to prairie ecosystems Don't know

5. Compared to the early 1800s, the number of black-tailed prairie dogs in the United States has:

Appendix A: Survey Instrument

Decreased dramatically Stayed the same Increased slightly Don't know

6. Some ranchers fear that rural prairie dog colonies will cause:

Cattle to break their legs in burrows Vegetation damage
All of the above Don't know

7. Prairie dog burrows provide nesting space and shelter for which of the following species:

Ferruginous Hawks Black-footed Ferrets Swift Foxes Don't know

8. After the plague infects a prairie dog colony:

colony The entire colony survives, frequently infecting other species that enter the colony
colony Some of the colony survives, frequently infecting other species that enter the colony
colony None of the colony survives, rarely infecting other species that enter the colony
Don't know

9. Compared to the communication abilities of other mammals, prairie dogs have:

Extraordinary communication abilities
Moderate communication abilities
Very limited communication abilities
Don't know

Appendix A: Survey Instrument

Section 1b—Please read this section ONLY AFTER COMPLETING Section 1a. Below are the answers to the previous questions, numbers 3 through 9.

3. How many litters of young (each litter is around 3 pups) do female prairie dogs have each year?

Correct answer: 1 litter. Prairie dogs have a slow reproductive rate and life expectancies around 4 years.

4. Within the prairie landscape, black-tailed prairie dog colonies are:

Correct answer: A very important part of prairie ecosystems. Black-tailed prairie dogs are considered a keystone species that creates a unique prairie environment. Their burrows provide shelter for many animals. For example, burrowing owls live in prairie dog burrows and thrive in the short grasses of a colony. They are also prey for many species. There is also evidence that cattle, pronghorn, and bison prefer the vegetation created in prairie dog landscapes.

5. Compared to the late 1800s, the number of black-tailed prairie dogs in the United States has:

Correct answer: Decreased dramatically. There were around 5 billion black-tailed prairie dogs a century ago. Their numbers have declined by 99% since then. They are in danger of extinction. Urbanization, continued poisoning, and the plague remain serious threats. This enormous decline in prairie dogs has dramatically reduced populations of black-footed ferrets, burrowing owls, ferruginous hawks, and swift foxes.

6. Some ranchers fear that rural prairie dog colonies will cause:

Correct answer: All of the above. However, there is no documented evidence of cattle breaking their legs in burrows. Prairie dogs prefer to live in areas with short grasses, but do not necessarily cause a detrimental reduction in the available vegetation. There is evidence that prairie dogs improve the quality of the forage available for grazing livestock. Historically, bison often preferred to graze around prairie dog towns.

7. Prairie dog burrows provide nesting space and shelter for which of the following species:

Correct answer: Black-footed ferrets. This mammal—one of the most endangered in the world—has been brought back from the brink of extinction through intensive breeding and reintroduction efforts, but they need very large prairie dog colonies for food and shelter to survive in the wild.

Appendix A: Survey Instrument

8. After the plague infects a prairie dog colony:

Correct answer: None of the colony survives, rarely infecting other species that enter the colony. There is an extremely low probability of transmission to humans because the disease wipes out a colony within a few days. Prairie dogs are not long-term hosts of the plague.

9. Compared to the communication abilities of other mammals, prairie dogs have:

Correct answer: Extraordinary communication abilities. Prairie dogs have the most advanced language documented in mammals (other than humans) due to their advanced alarm call system. They can create new 'words,' speak different 'dialects' in different colonies, and can even distinguish humans wearing different colored shirts.

Section 2—Based on what you now know about prairie dogs after reading Section 1b, please circle the answer you feel most accurately reflects your feelings about the above statement.

1. I enjoy or would enjoy having prairie dogs live in my community.

Strongly Agree Agree Neutral Disagree Strongly Disagree No
Opinion

2. I enjoy seeing hawks and eagles in my community.

Strongly Agree Agree Neutral Disagree Strongly Disagree No
Opinion

3. Prairie dogs in Denver play an important role in keeping the natural prairie intact.

Strongly Agree Agree Neutral Disagree Strongly Disagree No
Opinion

4. Lethal removal of prairie dogs should be the standard management practice on public lands.

Strongly Agree Agree Neutral Disagree Strongly Disagree No
Opinion

5. Prairie dogs are harmful to ranching.

Appendix A: Survey Instrument

Strongly Agree Agree Neutral Disagree Strongly Disagree No
Opinion

6. I support protecting prairie dogs in Denver.

Strongly Agree Agree Neutral Disagree Strongly Disagree No
Opinion

7. Restoring native prairie habitat in Denver is important to me.

Strongly Agree Agree Neutral Disagree Strongly Disagree No
Opinion

8. Plague outbreaks in prairie dogs are a threat to human health.

Strongly Agree Agree Neutral Disagree Strongly Disagree No
Opinion

9. I would consider a nearby prairie dog colony to be a positive amenity in a Denver neighborhood.

Strongly Agree Agree Neutral Disagree Strongly Disagree No
Opinion

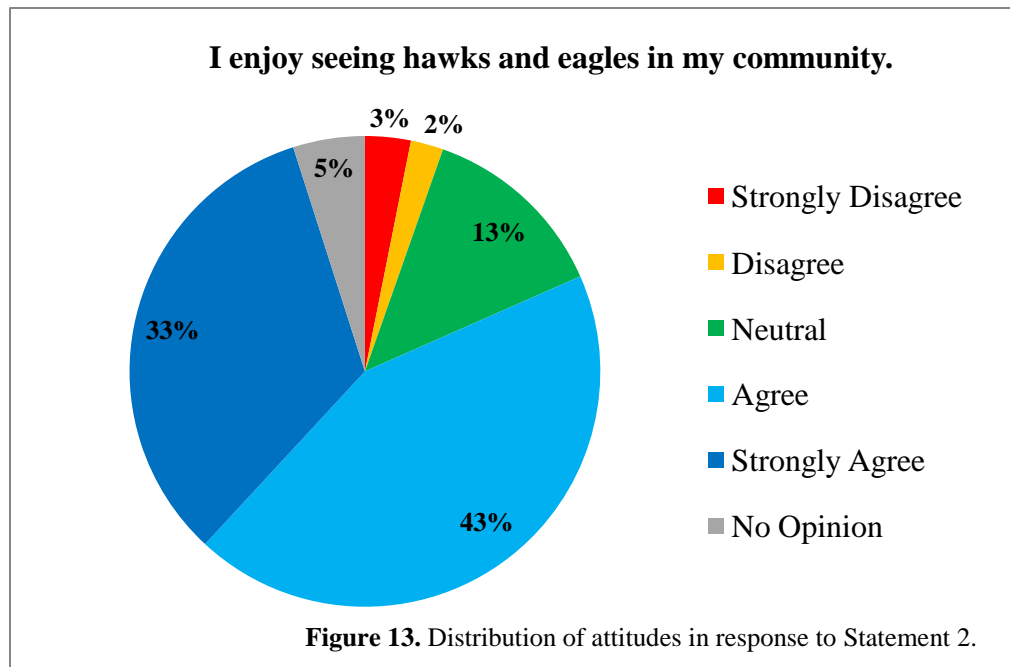
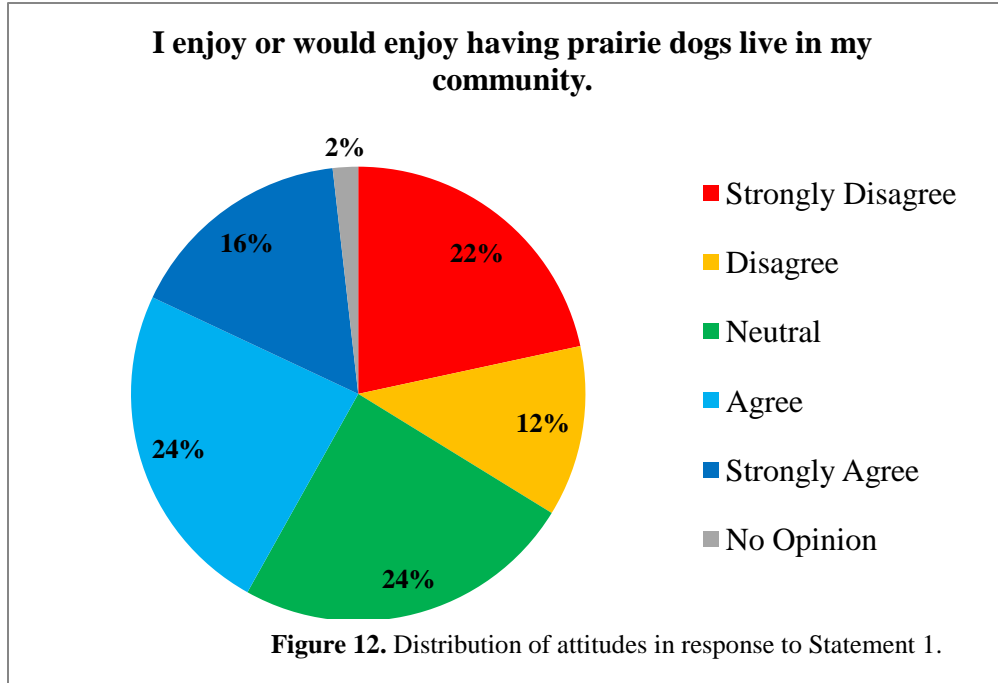
10. Prairie dogs inhabit flat, open space that would be better used for urban development.

Strongly Agree Agree Neutral Disagree Strongly Disagree No
Opinion

Thank you for completing the survey! We appreciate your time and effort. If you have any additional comments to share about prairie dogs, please do so in the space below:

Appendix B: Figures 12-21

Note: All pie charts were displayed so that the favorable attitudes towards prairie dogs appear in blue or dark blue. All unfavorable attitudes towards prairie dogs appear in red or yellow.



Appendix B: Figures 12-21

Prairie dogs in Denver play an important role in keeping the natural prairie intact.

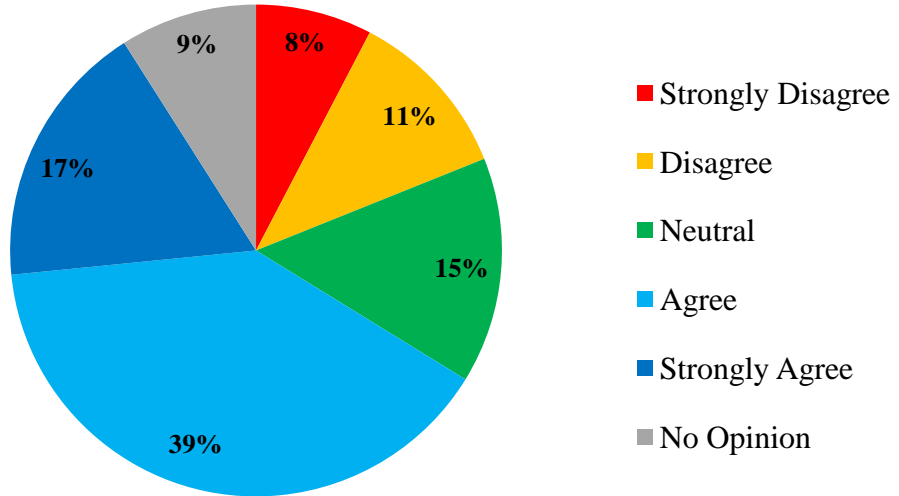


Figure 14. Distribution of attitudes in response to Statement 3.

Lethal removal of prairie dogs should be the standard management practice on public lands.

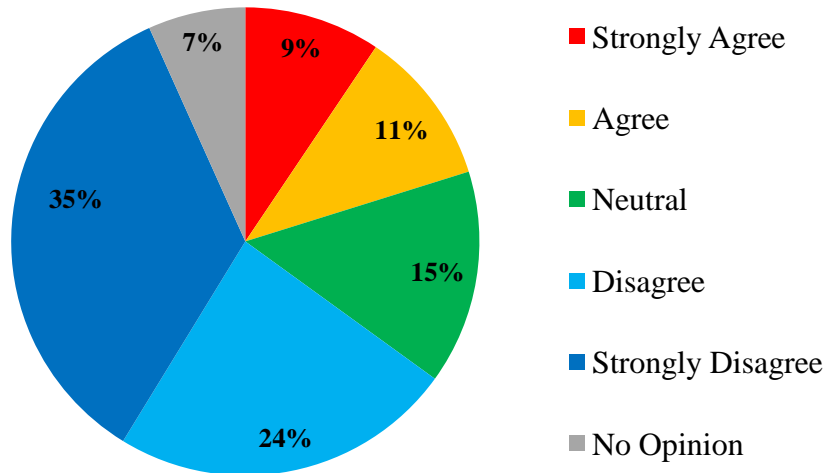
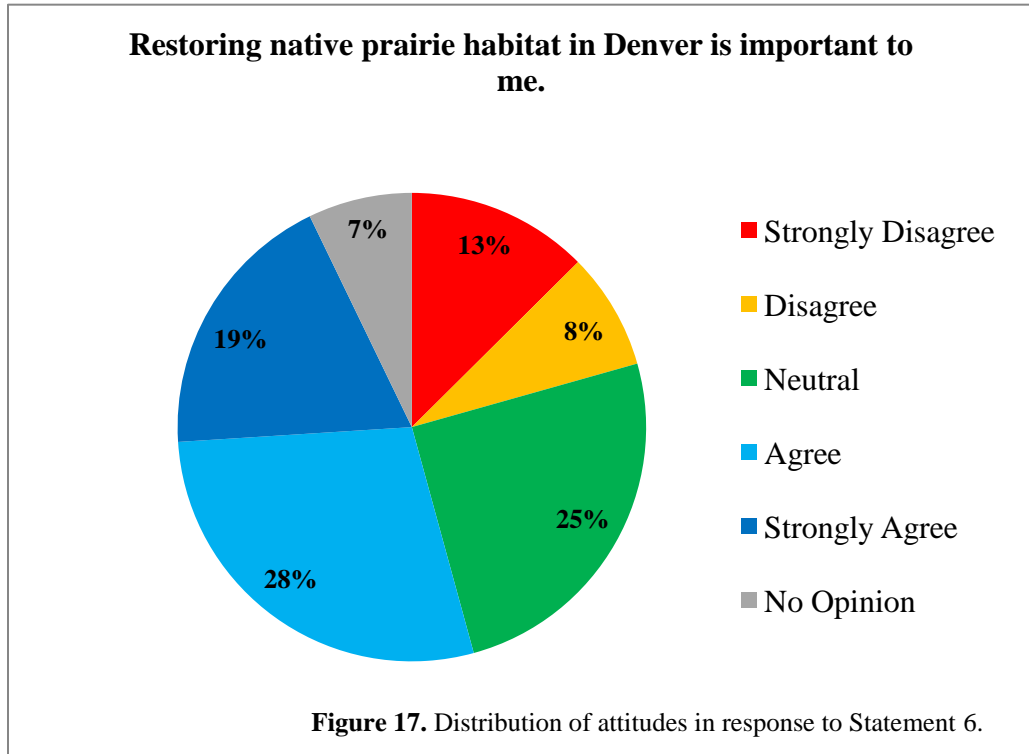
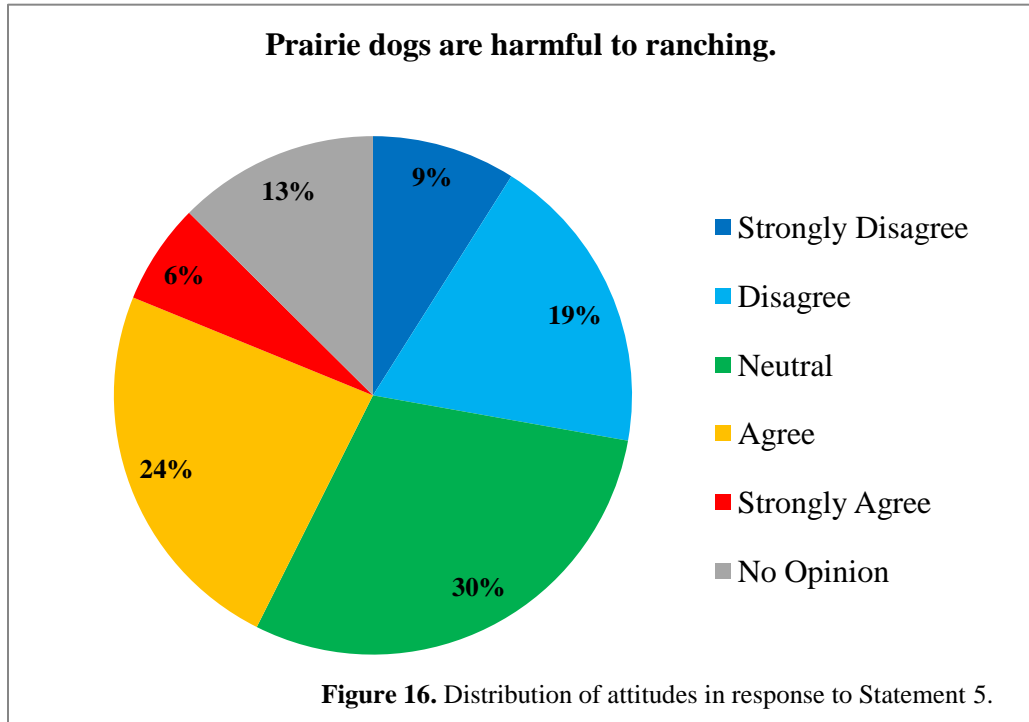
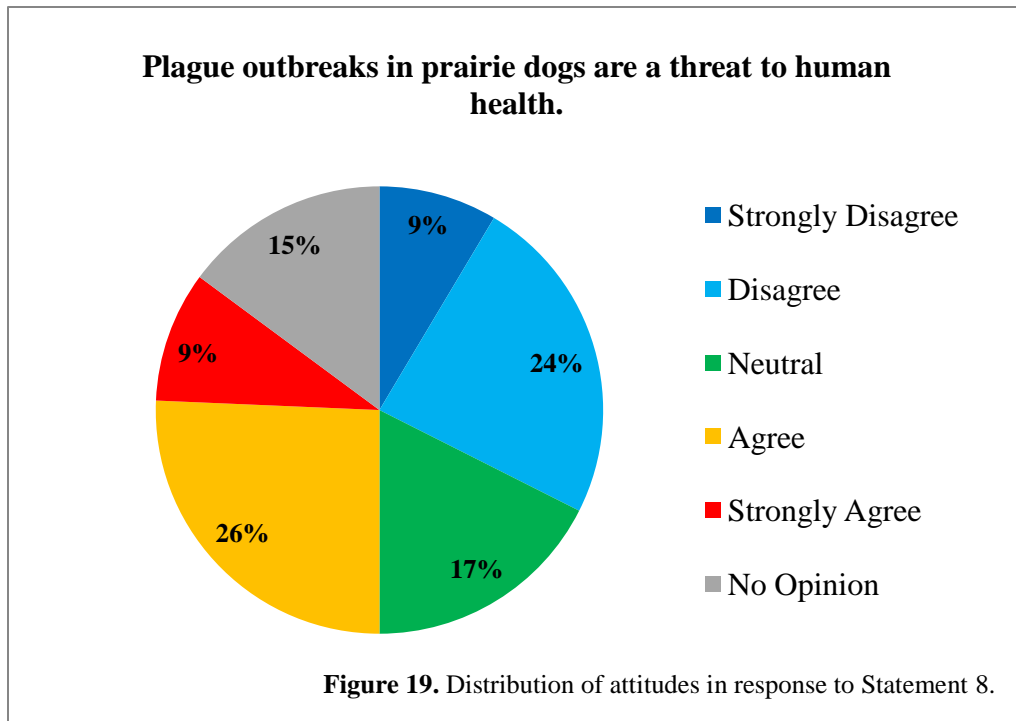
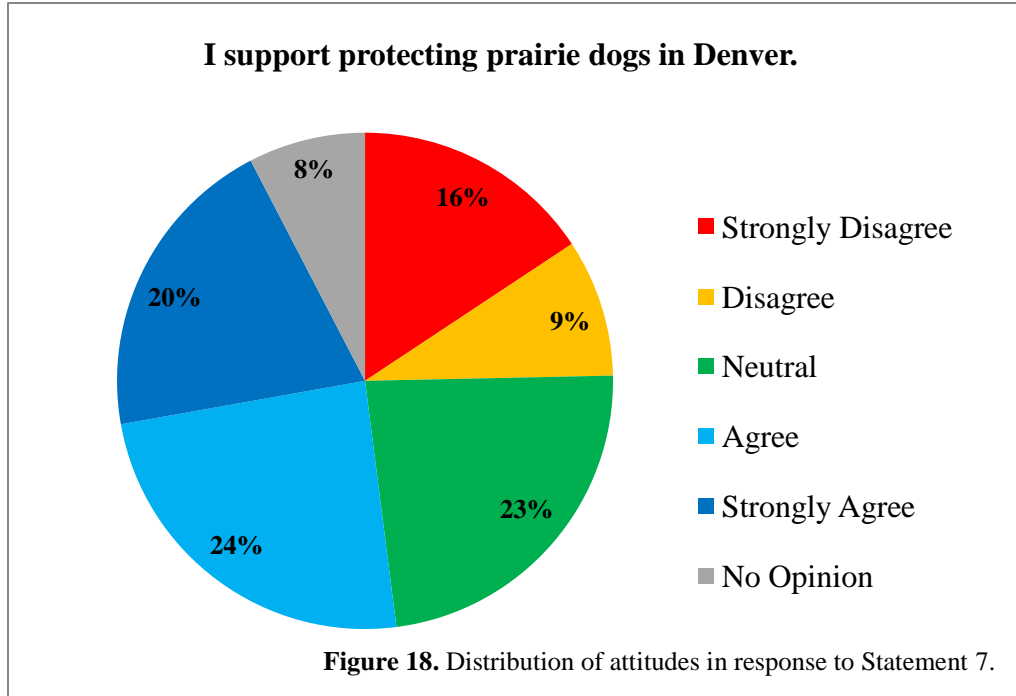


Figure 15. Distribution of attitudes in response to Statement 4.

Appendix B: Figures 12-21



Appendix B: Figures 12-21



Appendix B: Figures 12-21

I would consider a nearby prairie dog colony to be a positive amenity in a Denver neighborhood.

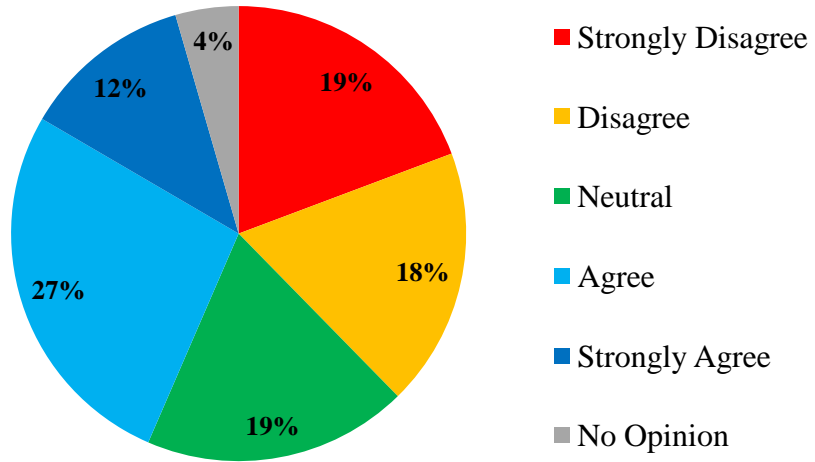


Figure 20. Distribution of attitudes in response to Statement 9.

Prairie dogs inhabit flat, open space that would be better used for urban development.

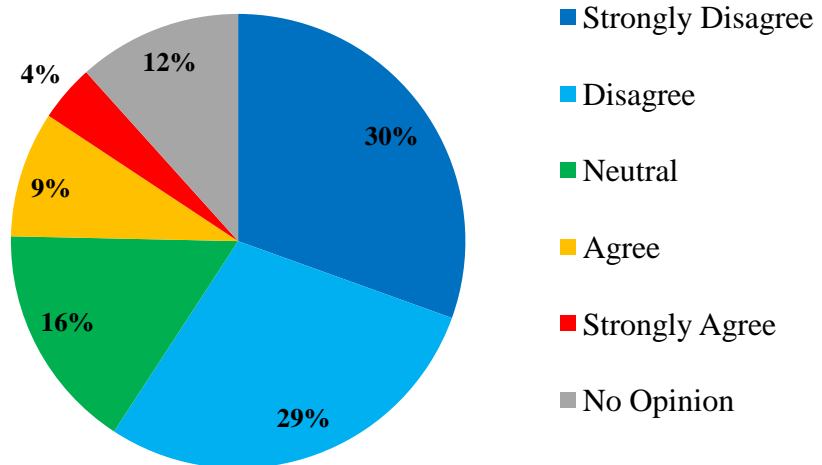


Figure 21. Distribution of attitudes in response to Statement 10.